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DEEP SKY

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Wide Field Astrophotography

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Galaxies along the Summer Milky Way

The Search for Supernovae

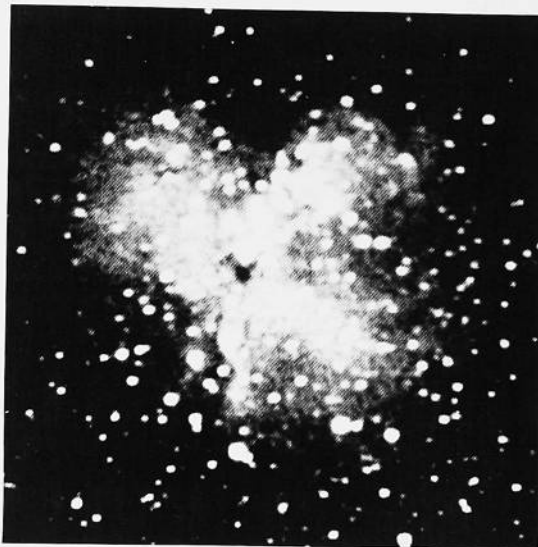
Observing the Veil Nebula





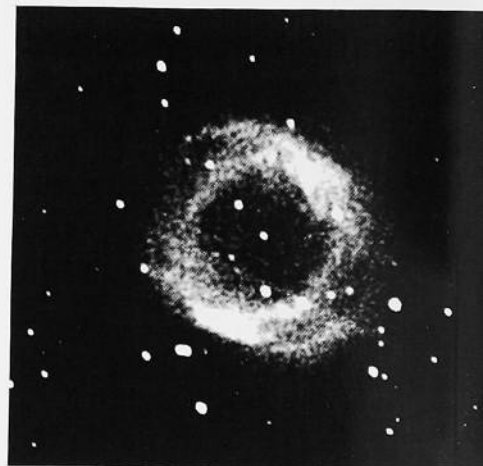
QUESTAR PHOTOGRAPHS THE DEEP SKY

Photographs by Hugh Entrop



The photographs shown are trimmed from 5 x 7 prints, enlarged from 35 mm. negatives. 1. A remarkable photograph of M8 taken at Table Mountain in central Washington with the Questar 3½. Exposure time one hour 25 minutes at f12.2 in turbulent air. 2. M51, the Whirlpool Galaxy in Canes Venatici, photographed on Tri-X through the Lumicon "Deep sky" filter with dry-ice camera, one hour 30 minutes at f11 with the Questar 7. 3. M16, the Eagle in Serpens, one hour at f9 with the Questar 3½ at Table Mountain. 4. M27, the Dumbbell nebula in Vulpecula, taken with the Questar 7. 5. NGC 7293, the Helix, taken with the Questar 3½.

Hugh Entrop has been a dedicated deep-sky photographer since 1965 when he bought his first Questar. His pictures are often accompanied by vigorous descriptions of the conditions he works under, which document his ability to overcome urban light pollution or rough mountain weather. But they show something else as well; they are dramatic proof that telescopes of small size and compact design can perform remarkably on the deep sky if their design and manufacture embody optical excellence, unequalled ease of use, and the portability which allows one to choose the best time and place for his astrophotography. Questar has been proving the point for forty years; let us share our experience and our enthusiasm with you.



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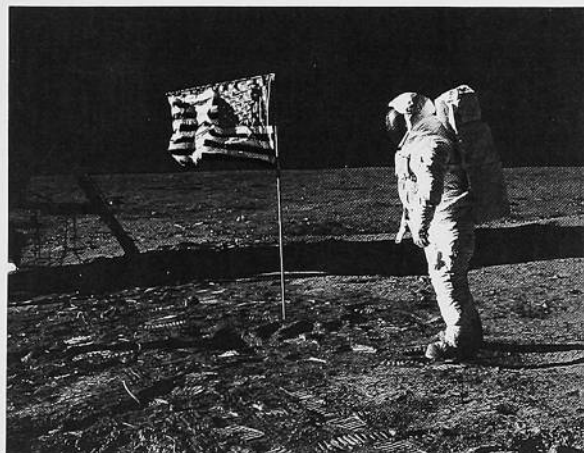
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DEEP SKY

THE MAGAZINE FOR DEEP-SKY OBSERVERS AND ASTROPHOTOGRAPHERS
FOUNDED IN 1977 BY DAVID J. EICHER

SUMMER 1990 VOLUME 8, NUMBER 3



Adventures in Wide-Field Astrophotography

by Chris Schur

10 *One of the most effective ways to capture large deep-sky objects is piggybacking your camera on a telescope and using fast film. Chris Schur reveals the ins and outs of wide-field photography.*



Galaxies near the Summer Milky Way

by Ernie Ostuno

18 *Who says you can't go out and observe galaxies all summer long? Ernie Ostuno describes a collection of faint galaxies that will challenge the most diehard observers.*



The Search for Supernovae

by Steve H. Lucas

24 *Supernova discovery has become the number one activity for amateurs interested in contributing data to science. Steve Lucas' SUNSEARCH network has paved the way for this important new direction in observing.*

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Magnitudes

Cover: NGC 6992-5, the eastern half of the Veil Nebula, photographed by Mike Sisk.

Opposite page: NGC 6960, the western half of the Veil, photographed by Martin C. Germano with an 8-inch f/5 reflector, hypered Tech Pan film, and a 45-minute exposure.

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At the Eyepiece

Astrophotography's Potential

Astrophotography has great potential. Although its heyday came in the 1960s and 70s and it is now threatened by the booming popularity of electronic imaging devices, photography nonetheless plays a unique, valuable role in amateur astronomy.

No other medium has the power to accurately show us exactly what deep-sky objects look like with such cold objectivity. Sketching deep-sky objects at the eyepiece, recording their appearances in our minds, or imaging them onto a CCD record only partial realities. When it comes to portraying these objects as they really are, astrophotography is second to none.

Contrary to the prediction of some, and the predilection of others, astrophotography is now stronger than it has been in years. As photo editor of both *Deep Sky* and *ASTRONOMY* magazines, I am currently receiving torrents of high-quality amateur astrophotos. The recent explosion of high-speed films with relatively fine grain structure is making certain types of astrophotography much easier than ever before.

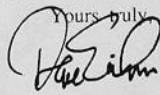
In this issue Chris Schur describes how to do one of the most popular types of astrophotography, wide-field piggyback photography. By mounting a camera on your scope, loading it with fast film, and employing a short focal length lens, you can record dazzling images showing wide swaths of sky — and guiding accuracy is as minimized as it can be.

Other articles cover a range of topics. Ernie Ostuno explores the many little-known galaxies found along the summer Milky Way and tells small and medium telescope owners how to successfully observe them. Steve Lucas, founder of the SUNSEARCH program, describes how amateurs can hunt for supernovae in other galaxies. Steve's article includes guest pieces by Robert Evans and John Griese, and Jenny Worsnopp.

Dennis Casper presents a surprising introduction to galaxy observing in Draco, demonstrating that many specimens are easily within the grasp of small scopes. Jim Meketa muses on the Veil Nebula, the great supernova remnant visible in Cygnus. These departments are followed by our regular coverage of news events, double stars, variable stars, small telescope observing, and challenging objects.

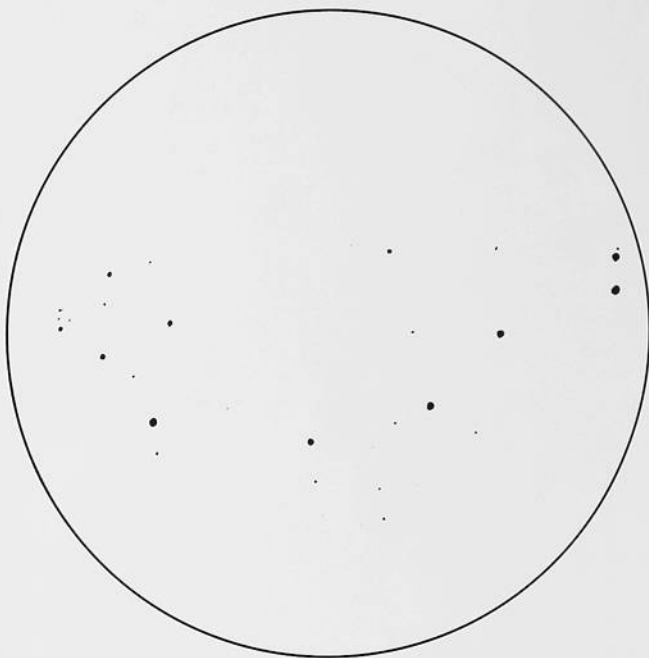
With this issue we welcome Mark Coco of Redondo Beach, California, as our book review editor. Mark is an expert observer currently employed at Celestron International. We look forward to his engaging evaluations of books relevant to deep-sky observing and hope you will join us in welcoming him.

Finally, two close colleagues who have contributed much to this magazine and its editor are leaving Kalmbach Publishing Co. to pursue other projects. I will miss Steve Cole and Jeff Kanipe very much — their energy and enthusiasm will not be forgotten.

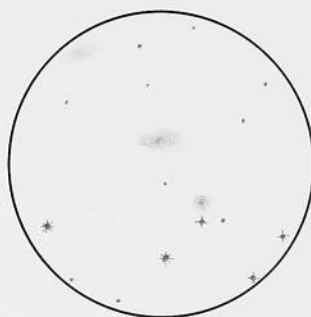
Yours truly,

 Dave Eicher

Letters to Deep Sky

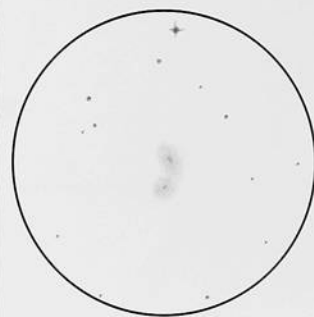
What's that Star?



The "Baby Scorpion" asterism in Aquarius sketched by William P. Clarke using 11x80 binoculars.



The NGC 3190 galaxy group sketched by Miro Ilic (6-inch f/10 reflector at 70x).



The NGC 3226-7 galaxy pair sketched by Miro Ilic (6-inch f/10 reflector at 70x).

What's that Star?

Dear Dave / I was happy to see that you published my letter about the star near M51 in the autumn 1989 issue. Meanwhile, I have checked my calculations and discovered that I guessed wrong about the suspected star type. If the star is a K or M type giant or subgiant and you compare absolute magnitudes for such stars with the visual magnitudes of the star I photographed, the result is an enormous distance modulus. This places the star in question at the very great distance of about 4000 light-years.

The star in question must be a

relatively near K or M type dwarf. If the star is moving toward or away from us closing a very sharp angle to our line of sight, it may be very near us. But if the star's motion is tangential to our line of sight it must be at least 50 light-years away.

On another matter, I am enclosing some galaxy sketches that I hope you will enjoy and share with your readers. Keep forward *Deep Sky* crew.

Miro Ilic
 Iva Voajnovica 48
 Dubrovnik 50000
 Yugoslavia

DEEP SKY



Thompson's mystery object is a rich complex of nebulosity involved with a bright star cluster. Photo by Gregg D. Thompson (10-inch f/5.8 reflector, hypered Ektar 1000 film, 20-minute exposure).

The Baby Scorpion Revisited

Dear Mr. Eicher / In your spring 1989 issue Miro Ilic described the "Baby Scorpion" asterism he found in Aquarius. I am sending a sketch of the region made with 11x80 binoculars. The asterism fits well in the field and is quite distinctive. This area is well represented in the upper right-hand corner of chart 305 in *Uranometria 2000.0*, volume 2. I wonder if these stars, being of similar brightness and spectral type, lie at roughly the same distance and are a gravitationally-linked group.

I have been engaged in a stimulating correspondence

with Miro since I read his letter in your magazine. Thanks for providing a forum that makes the start of such exchanges possible.

William P. Clarke
2211 Judson Street, Apt. 11
San Diego, CA 92111

Thompson's Mystery Object

Dear Dave / Here's a mystery object that's sure to stump some of the best deep-sky sleuths. Like many of the others I have discussed it can be glimpsed with a keen naked eye under good conditions and the smallest optical aid reveals a bright, hazy glow not far from a ruddy

6th-magnitude star. This star is visible in the bottom right of the accompanying photo.

Small telescopes at low power show this object as a double or even triple nebula. Apertures larger than 6-inches typically resolve the southernmost nebulous spot into stars. An O III filter confirms that the other two bright nebulous regions are rich in doubly-ionized oxygen more so than H II. The fainter and smaller of the northern nebulous patches is the most difficult part to spot in amateur telescopes.

The photo displays how the solar winds from the star cluster has blown away the bulk of the

remaining gas from which the cluster formed and left a dark background against which the cluster members glow. The photo is a 20-minute exposure made at the prime focus of a 10-inch f/5.8 reflector, made with hypered Ektar 1000 film.

Incredibly, although this object is about $1/4^\circ$ in diameter and easy to see in finder scopes, it is virtually never discussed by amateur observers. Can anyone identify this puzzling denizen of the sky?

Gregg D. Thompson
Springwood Observatory
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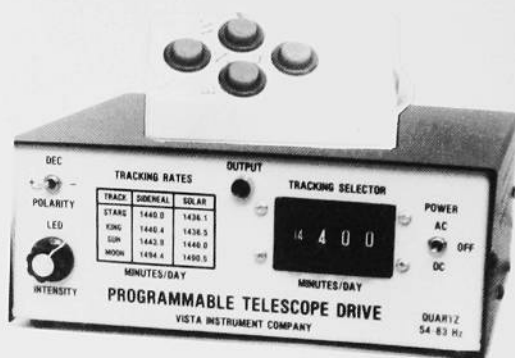
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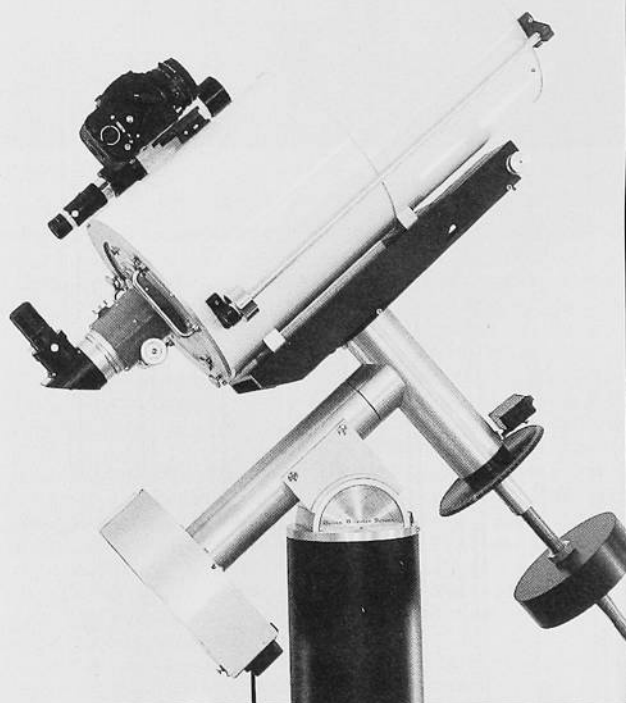
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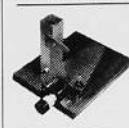


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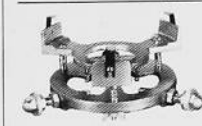
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Adventures in Wide-Field **Astrophotography**

by Chris Schur

Skyshooting with a wide-field camera is astrophotography in its purest form. In a single frame it is possible to capture dozens of deep-sky objects. Probing the sky with such a system will reveal many fine details that even the best charts lack. You can also use wide-field photographs as observing tools to help pin down many elusive objects that are visually challenging. Many useful projects can be accomplished with a simple 35mm camera, such as charting a favorite region for later study, nova patrols, seeking comets and recording their motions in the sky, and mapping the hundreds of dark nebulae along the plane of our galaxy.

The concept of wide-field astrophotography is simple. Attach a small camera with either a wide-angle or telephoto lens to the telescope tube. While the clock drive in the mounting moves the tube at the same rate as the stars, the camera's field of view remains fixed and time exposures can be made. In reality this task is not so simple. However, with a little care and patience any determined individual can produce acceptable results. In theory any type of camera will suffice, but the variety of films and lenses available for 35mm SLR cameras make these cameras most suitable for the job. This allows a choice from the three most common types of lenses: wide-angle, normal, and telephoto. The only other requirements for shooting are an equatorial mount and a clear sky.

Applications of Wide-Field Astrophotography

Wide-field astrophotography is most people's first step toward experiencing more of the universe than can be seen with the naked eye or telescope. Because of the cumulative effect of light building up on

film during an exposure, your camera is far more sensitive than your eyes at seeing faint objects and subtle colors in the sky. Nearly invisible objects such as dark nebulae, strongly colored stars, and extended faint emission nebulae are clearly revealed in 5- or 10-minute exposures.

A quality lens can make the difference between an average shot and a superb one. But how can you evaluate a good lens for astrophotography? All too often

many of the name brand lenses offered for 35mm cameras are unsuitable for skyshooting due to various aberrations or distortions. A lens that may be perfectly suited for terrestrial photography may be useless for astrophotography.

The type of subject you will be shooting will for the most part determine the type of optics you need. For example, a large aperture is essential for recording the faintest possible star images possible for nova patrols

or star mapping. However, a fast focal ratio is the only choice for recording dim, diffuse objects such as emission nebulae or dark nebulae. In short, the diameter of the objective lens determines the faintest stars you can record, while the focal ratio limits the faintest extended objects recorded. Fortunately, telephotos and wide-angle lenses are more suitable for photographing extended objects that are far too large and faint for the telescope to record.

No one lens system is perfect. All lenses are plagued by various defects, some more important than others. Probably the worst distortion is coma. This aberration is usually seen as comet- or parachute-shaped images near the edges of the field that worsen as you move further off axis.

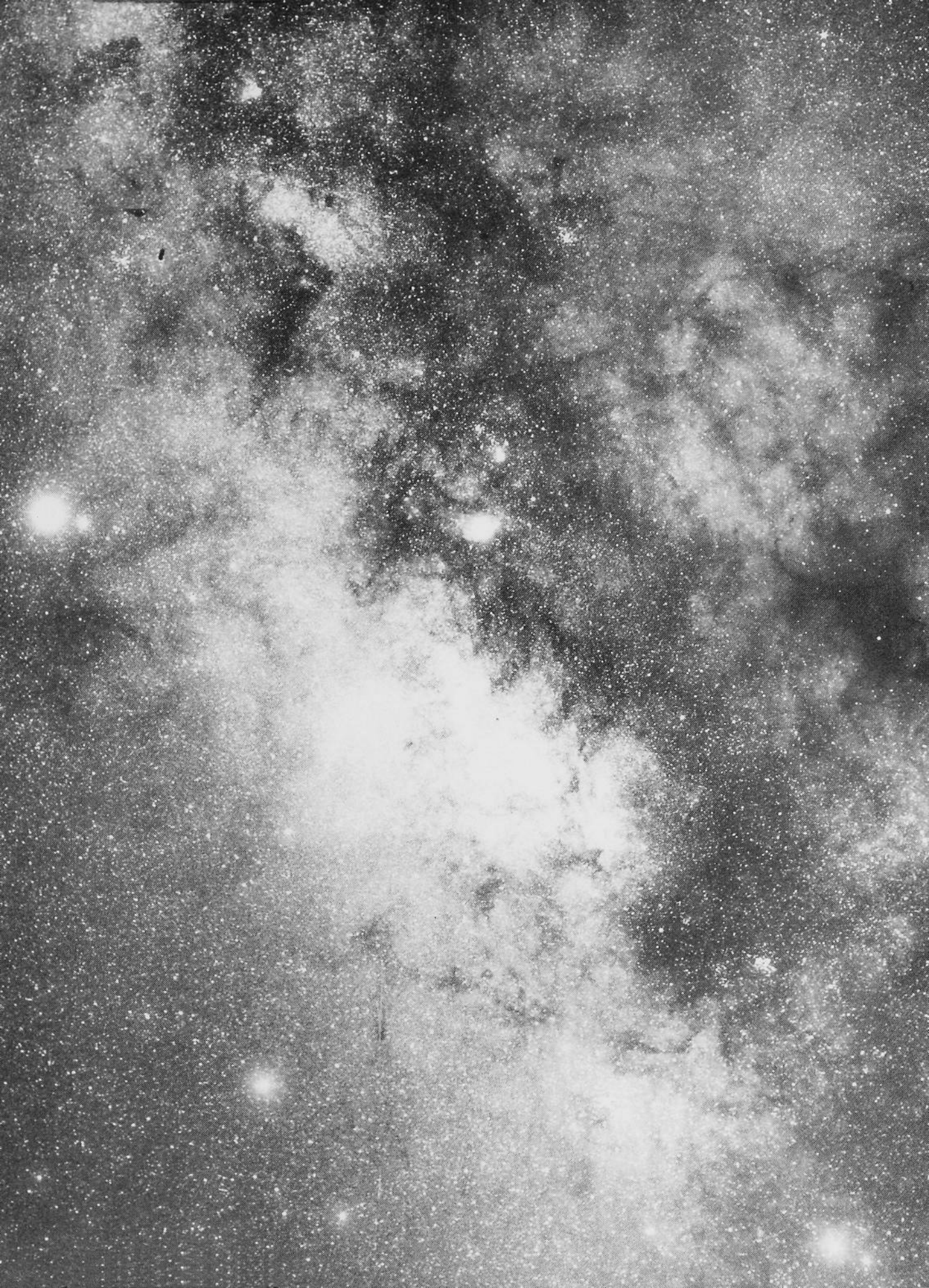
Another type of distortion is chromatic aberration, which is caused by the inherent curves in the glass itself. It is characterized by swollen star images in the center of the field and possibly a blue halo around bright star images. The inability of lenses to bring all colors to a common point of focus is the cause of this condition.

Vignetting is the third most common defect in lenses. This can be seen as a falling off in the intensity of the light striking the film near the edges of the frame. In extreme cases vignetting can cause the photo to look like it was shot through a porthole.

The fourth difficulty with wide-field systems, and one of the more difficult to remedy, is field curvature. This occurs when the center of the field is at a different focal point than the edges of the frame. Often this may not be distinguishable from coma in off-axis images, but in severe cases the lens may have to be rejected for use in astro-



Eta Carinae and the southern Milky Way photographed by Chris Schur (50mm f/2.8 lens, hypered Tech Pan film, 15-minute exposure). Opposite page: The core of the Milky Way (with Mars) photographed by Martin C. Germano (50mm f/4 lens, hypered Tech Pan film, 35-minute exposure).



photography.

Once you choose a lens, test it for suitability. The stop-down test involves mounting the camera with the prospective lens system on the back of a driven telescope. Load the camera with a fast color film, preferably slide film. Aim the scope/camera combination at a bright star field and engage the drive. Allow a few minutes for the drive to take out the slack in the system. You will not need to guide on any particular star for this test. With the lens all the way open, say at $f/2$ for a typical 50mm lens focused at infinity, adjust the shutter speed to "B". Open the shutter and expose for one minute. Now advance the film and close down the lens one stop. Repeat the one-minute exposure. Continue stopping down the lens and exposing until you get to $f/5.6$ or $f/8$. The final result will reveal which focal ratio will be acceptably sharp.

The second test, called the trailed focus test, involves turning off the drive or mounting the camera on a stationary tripod. Aim the camera at a similar star field and open the lens up all the way. Open the shutter and let the stars trail for two minutes. Now carefully cover the lens with a dark cloth or lens cap and, using a dim light to read the lens, rotate the focus ring on the lens about half a millimeter as seen on the distance vernier toward the close-focus position. Uncover the lens for another two minutes and then recover it. Repeat this process on the single frame until five or six steps are completed. Close the camera's shutter and repeat the whole test if desired. The end result will determine where the best stellar focus will be achieved. Anytime colored filters, especially red ones, are used in front of the lens, this procedure will have to be repeated.

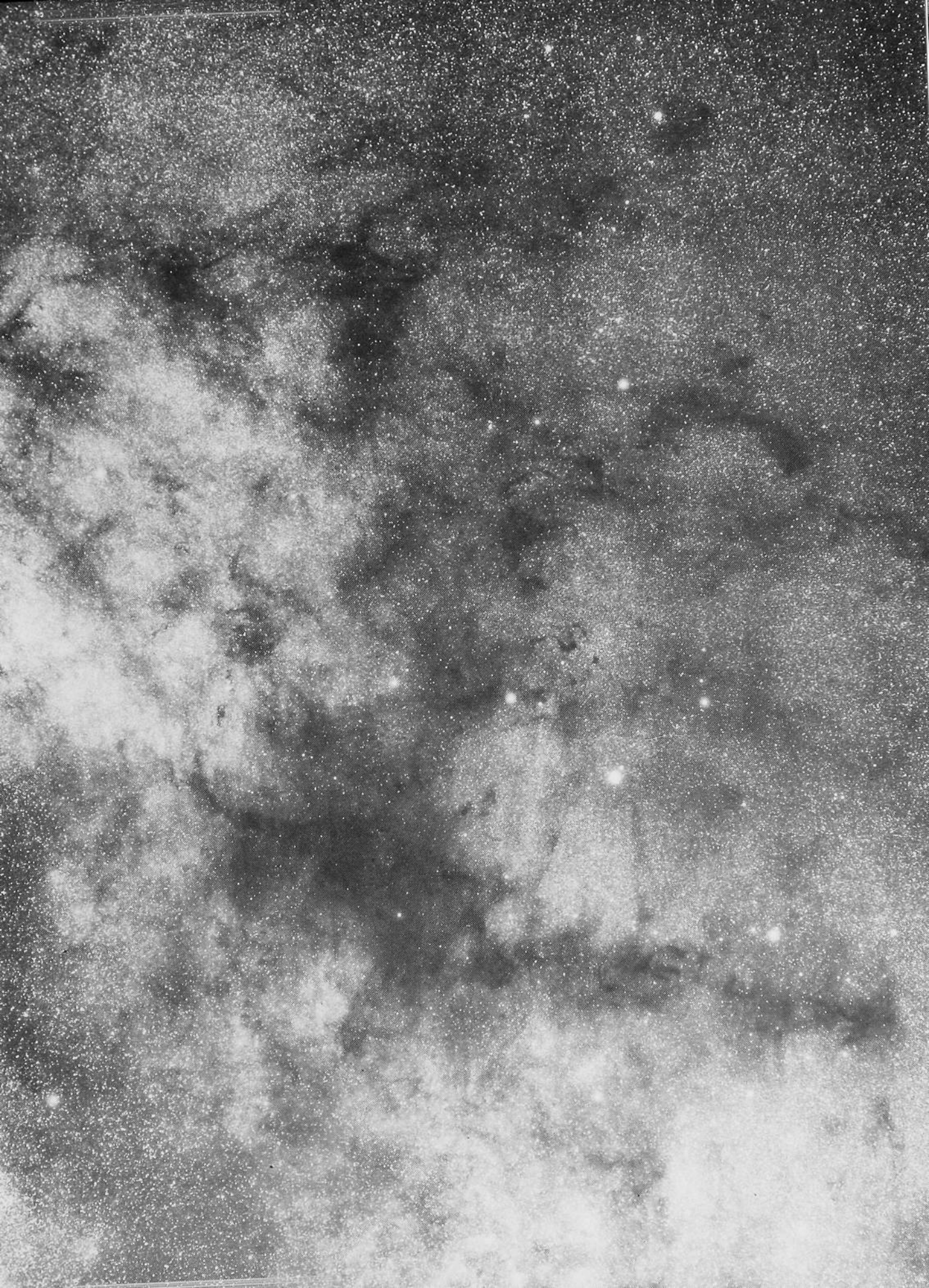
When the film is processed carefully study the slides with a minimum of a ten-power magnification. A 25mm eyepiece turned around and used as a magnifier works well. Don't use a slide projector for your evaluations because they introduce their own distortions. For the first test examine each slide in the sequence carefully, starting with the fastest focal ratio. Note the appearance of the stars in the center and the corners of the frame. There will be a point where the stars in the center will appear very sharp and the images in the corners will be



The Scutum starcloud photographed by Chris Schur (300mm $f/1.5$ lens, Fujichrome 100 film, 8-minute exposure).



Mars in Sagittarius photographed by Chris Schur (50mm $f/2.8$ lens, Fujichrome 100 film, 15-minute exposure). Opposite page: The galactic "dark horse" near Theta Ophiuchi photographed by Brad Wallis (300mm $f/8$ ApoRonar lens, 4 by 5 inch hypered Tech Pan film, 240-minute exposure).





The Eta Carinae Nebula photographed by Chris Schur (180mm f/2.8 lens, Fujichrome 100 film, 20-minute exposure). Opposite page: The North America Nebula region photographed by Abdul Hadi Marafie at the Wafra Observatory in Kuwait (80mm f/1.4 lens, hypered Tech Pan film, 30-minute exposure).

close to pinpoints. This will be your best compromise between photographic speed and sharpness. This occurs in most lenses between $f/2.8$ and $f/4$. You must decide whether a small amount of coma at the edge of the frame is acceptable or whether the frame must be razor sharp to the edge at the expense of a much longer exposure. A good compromise is one stop down from wide open for good performance on extended objects and reasonably sharp images at the edges of the field.

When examining the results of the second test, look for a progressive enlargement in the width of the trailed star images. This indicates that the lens is at best focus in its infinity position. However, in half the lenses you may encounter, especially the older, used ones, they will focus in a slightly different position. Here you will see the trail narrow after one or two steps and then become wider again. Check your notes for the position of the lens that corresponds to the narrowest trail. Mark this position on your lens by either scribing a fine line or arrow into the focus ring or by putting tape on the ring and marking it in pen. This will be the position of true focus at any

focal ratio and should be used for astrophotography.

Films for Wide-Field Astrophotography

There is a wide selection of films on the commercial market suitable for various forms of terrestrial photography, but only a handful of them are suitable for skyshooting. What are the characteristics of a good film suitable for wide-field astrophotography, and what should we expect from them? Certainly, high film speed comes to mind for many budding astrophotographers, yet with the fast lenses used in wide-field work this may not be the best choice. Many of the objects recorded will be small on the frame, so a fine-grain, slower film works much better.

With much more light from fast focal ratios relative to prime-focus astrophotography, sky fog will be more of a problem. A higher contrast film is desirable to help differentiate the nebula from the bright sky background. Another desirable characteristic is good red speed. Many of the targets most suitable for wide-field photography are emission nebulae. Since their primary color is a deep red from H-alpha emission, they

require a film that responds adequately to this wavelength. The best film choice will also include low reciprocity failure, which is the film's ability to keep on recording fainter and fainter objects in long exposures. Most off-the-shelf films are poor in this regard.

Unfortunately, no single film has all of the characteristics needed. In fact, most color films are totally unsuitable because of low contrast or very low red speed. Fortunately there are a few decent films that meet most of the criteria. For color slides, Ektachrome 400 is still the best for red sensitivity and high contrast. It has a fairly high reciprocity failure in exposures longer than fifteen minutes, however. Agfachrome 1000 slide film has been very well received despite its somewhat coarse grain. It has good red speed and a very pleasing neutral colored sky background, even with light polluted skies. I recommend this film for beginning sky shooters. For color prints, Kodak VRG 400 works fairly well, but many have had surprisingly good results with the Konica SR1600 film. For black-and-white users, hypered Tech Pan 2415 reigns supreme. In lieu of a hyper tank, TMAX

400 performs well for Milky Way photography but is poor in the red region of the spectrum.

Getting Started in Skys shooting

The most basic requirements for wide-field photography are a 35mm camera, a suitable lens, and a tracking platform. This can be a barn door type mount or, better yet, an equatorially mounted telescope with a camera bracket affixed to its tube. After the mounting is polar aligned and tracking on a suitably bright guide star contained within the camera's field of view, open the shutter for ten or fifteen minutes. As the exposure progresses keep the guide star centered in the field. When you're finished close the shutter, advance the film, and take another shot. Before you know it you'll have a nice collection of constellation shots or Milky Way fields.

To get the most from wide-field photography consider each step in detail. Start with polar alignment. If you're even a degree off the true pole, you will not get accurate tracking due to field rotation. In a 35mm or 50mm lens shot this can obliterate the fine details in the outer half of the field. To prevent this, polar alignment





The Orion Nebula photographed by Chris Schur (300mm f/1.5 lens, Fujichrome 100 film, 8-minute exposure).

within a quarter of a degree is desirable.

Over the years there have been many complex methods to get the axis of a telescope aimed at the exact pole. However, I suggest using a method that has proven effective and takes only about five minutes. Unlike the classic method of waiting around for hours watching the guide star drift to determine whether you are east or north of the true pole, there is a much simpler method: aim the right ascension shaft directly at the pole with an offset bore site. To accomplish this you will need a 6x30 finder and a V-block to rest on the polar shaft of the mounting. The finder rests in the other side of the V-block and the whole mount is aimed right at the pole directly using the chart in *Burnham's Celestial Handbook* or *Uranometria 2000.0* for reference.

Also consider how your camera is attached to the scope. Care should be taken to attach the camera as rigidly as possible. A simple ball-joint mount available in any well-stocked camera store will work well for 35mm and 50mm lenses, but for anything longer in focal length additional support is essential. Even a short wooden brace

holding the front of the lens works well. There should be no bending, vibration, or slow shifting between the two optical systems. Guiding is also critical to the success of an astronomical photograph. A typical arrangement is a 12mm red LED illuminated crosshair eyepiece and a 2x Barlow for longer lenses. For 35mm and 50mm lenses, 50x to 100x magnification will be required with fine-grained films. For 135mm to 200mm lenses, 100x to 150x is suggested, and for up to 400mm long lenses you may need 90x or even 200x for best results.

The First Picture

The procedure is to first align the camera with the main instrument. You may have to offset it a bit so that you don't include the telescope tube in the bottom of the frame. Next, aim the camera at the subject and carefully compose it the way you like. With a low-power ocular inserted in the main scope, scan around a degree or so until a suitable guide star appears within the field. How bright must a guidestar be to be useful? Bright enough to be clearly visible in the guiding eyepiece at the guiding magnification with the reticle suitably illumi-

nated. After a while you will get a feel for what brightness this star must be. You might like to recenter the camera on the subject at this point, but with a wide-field lens this is not usually a concern.

With the guiding ocular installed and the cross hairs lined up to match east-west and north-south, check the buttons on your drive corrector's hand paddle to make sure the star can be moved in any direction in the guiding field. Center the guide star, open the shutter and lock down the cable release. Recheck the guidestar and start your timer. You're now ready to open the shutter and begin your first photo.

Here's a tip for longer exposures: Most people find that a suitable exposure is on the order of thirty minutes with a 400 speed film. But after fifteen minutes or so, they cannot go on because of fatigue. One solution that works well is to guide for that first fifteen minutes and put the lens cap back on loosely or cover the lens with a small dark cloth. Take a ten-minute coffee break, recenter the guide star if needed, and remove the loose lens cap or dark cloth. Then continue on with the exposure for another fifteen minutes.

This way you guide the second half of the exposure fresh and alert. In this technique has allowed many amateurs to measurably improve their results.

Processing the Film

After a long night at the guide scope you'll have a roll of film ready for processing. If you have a darkroom at home you can develop the photos the same night. But these days development is typically in the hands of the professional photo lab. If this is your situation, I strongly recommend using slide films. The lab can do little harm to the color balance of the original shot and usually the higher contrast of the slides themselves yield the most pleasing results.

However, a warning is in order. Since nearly all photo finishers do not know a dark sky background from a poorly exposed terrestrial shot, they may set the automatic cutting and framing machine to chop your precious astrophotos to bits. There are two ways to prevent this. First, tell the photo finisher to develop but not mount or cut the film. Second, take some terrestrial shots at the beginning and end of the roll, and the processor will have something to line up on the



The North America Nebula photographed by Vince Mele (300mm f/1.5 lens, hypered Tech Pan film, 10-minute exposure).

cutting machine.

For prints the problem is complicated by the printing process itself. During this process the lab technician usually botches up the colors, nearly always printing them too dark. If you must use print film a workable solution is to get real friendly with a local one-hour photo lab and work with them to obtain suitable results. The goal is to achieve a nearly colorless medium dark grey background in your prints so that maximum detail shows through. For commercially processed black-and-white prints specify "print for maximum contrast" on the envelope. This usually works well.

Troubleshooting

Despite careful polar alignment and accurate tracking, flexure caused by a poorly designed camera mount or improperly balanced tube assembly can ruin a potentially fine shot. Most astrophotographers tend to overlook balance as a cause for poor results. It has been demonstrated that most mountings track best if the balance is shifted on the counterweighting such that the scope slowly leans eastward when the right ascension clamp is loosened. In other words, it is much

better to have the gear pull the telescope than the telescope pulling forward on the gear. Tracking can be up to ten times better one way than the other, so be certain to check the balance just before each shot, or at least when moving to a new part of the sky.

Flexure can ruin a potentially well-guided shot, too. All too often poor guiding is blamed when in reality the tracking was good but the camera flexed a bit relative to the guiding telescope. To eliminate this, a sturdy mount must be devised to ensure a rigid connection to the back of the telescope tube. A wooden saddle may have to be installed on the tube itself with straps if the tube material bends with the weight of the camera. Cardboard tubes or those made from fiberglass should be suspect.

Even if you are guiding perfectly and have eliminated both flexure and mechanical problems, you may wish to know just how accurate you will need to track to obtain best results. By using the simple rule of thumb that a 50mm lens with fine-grain films can just resolve a tracking error of about an arc-minute (60 seconds), you can scale your tracking tolerance

accordingly. For example, a 135mm lens, 2.7 times longer in focus than the 50mm lens, will resolve an error 2.7 times smaller, or $60 \text{ arcseconds} / 2.7 = 22 \text{ arcseconds}$. Your tracking must be such that the guide star is kept within an imaginary boundary of this size. Take a look at several double stars of known separation to determine what your tolerance will look like in the guiding eyepiece. For the 35mm lens in this example, the double star 61 Ophiuchi would fill the bill nicely.

Filters for Wide-Field Astrophotography

For combatting light pollution or improving the contrast in emission nebulae, filters are becoming an indispensable part of the skysooter's equipment. There are basically two filters useful for wide-field work. The first type is the deep red filter such as the Wratten #25 or the Lumicon H-alpha pass filter. These not only cut natural or artificial sky fog substantially, but provide a big increase in the contrast of emission nebulae. Black-and-white film must be used with these filters; the only one with great red sensitivity is hypered Tech Pan.

For color photography I recommend Lumicon's Deep Sky

filter, a proven contrast booster and skyglow cutter that has probably claimed the title of the best photographic filter on the market. I do not recommend this filter for ultrawide-angle lenses because of the restricted acceptance angle of its multi-layer construction. But for 50mm or longer focal length lenses it works well. With the filter exposures can be lengthened by about a factor of three without sacrificing details in star clouds or other objects in the field.

With some care and patience wide-field astrophotography will become one of the most enjoyable parts of the hobby. You can collect a beautiful set of constellation slides or prints along with close-ups of favorite objects and regions. Wide-field skysooting will allow you to see much more of the universe than is possible by normal vision alone. The rewards of capturing a small portion of the Galaxy permanently on film for everyone to enjoy is something anyone can be proud of.

Chris Schur is an accomplished astrophotographer who lives in Payson, Arizona.

Galaxies along the Summer Milky Way

by Ernie Ostuno

From areas where the skies are truly dark, the stretch of Milky Way from Cassiopeia to Scorpius is one of the most impressive and awe-inspiring sights there is. The dark rifts of dust seen in intricate detail against the brilliant star clouds make for a fascinating sight on a clear summer night. Most deep-sky observers are familiar with the numerous clusters and nebulae to be found here. Unlike the fainter portion of our Galaxy that we see in winter, this enormous treasure trove of deep-sky objects can be explored without frequent trips indoors to thaw out. If you can stand dewing problems and the occasional mosquito, then observing this part of the sky is a breeze.

As I discussed last winter, galaxies can be observed in amateur telescopes surprisingly close to the plane of the Milky Way. Even though we see a much thicker, dustier section of our galaxy in summer, you still find galaxies showing up in some unexpected places.

We begin our search in the rich starfields of extreme eastern Scorpius near the Lupus border. **NGC 6000** is a 13th-magnitude spiral that appeared in the 10-inch as a round, low surface brightness patch of light with a faint star almost touching it to the northeast. Although not an easy mark, it is the brightest galaxy in Scorpius.

From here move to the bright globular cluster M80. In this area, known for its stellar associations and dust clouds, lies **IC 4596**, a small 15th-magnitude edge-on spiral galaxy. In the 13-inch scope I found high power necessary because of the galaxy's small size. It was only glimpsed with averted vision, but observers with large scopes living in the southern United States should get a better view of it.

From here we cross the cen-

tral bulge of our home galaxy and continue eastward to **NGC 6822**. This large irregular system measures 10' by 9' and has a total magnitude of 9.4. A member of the Local Group of galaxies, it was discovered by E. E. Barnard less than 1° southeast of the bright planetary **NGC 6818**. In the 10-inch scope it appeared as a large, faint glow, elongated north-south. With the 13-inch using high power and averted vision I noticed a mottled appearance, suggesting the many small star

clouds and HII regions that show up on observatory photos of this galaxy.

Lying 2° northeast are the barred spirals **NGC 6835** and **NGC 6836**. Both glow at magnitude 13.6 and can be compared in the same telescopic field. **NGC 6836** is a round, face-on spiral; **NGC 6835** is an edge-on spindle. After scouring these objects hop across the Aquila border to **NGC 6814**, a 12th-magnitude Seyfert galaxy. Use high power to look for this galaxy's tiny, stellar nucleus.



The low surface brightness galaxy NGC 6822 in Sagittarius photographed by Steve Quirk (10-inch f15.8 reflector, hypered Ektar 1000 film, 20-minute exposure). Opposite page: The gorgeous face-on spiral NGC 6946 is one of the greatest galaxies along the galactic plane. Photo by Chuck Vaughn.

Continuing northward we come to **NGC 6821**. This 14th-magnitude barred spiral lies 1° north of the faint globular cluster Palomar 11. In the 10-inch scope it is best visible with averted vision as a small, round patch. In the same low power field is **MCG 01-50-001**, a 14th-magnitude edge-on spiral.

Moving closer to the galactic equator brings us to some challenging non-NGC galaxies that lie amidst the thickening dust cloud. **UGC 11481** is a 15th-magnitude spiral some 5° south of Altair. With the 13-inch scope at high power I spotted this object as a small, round blur surrounded by faint field stars.

A magnitude-15.6 object, **Zwicky 397.014** is a target for really big scopes. Sixteen-inch and larger instruments show this object as a tiny edge-on spiral. I have included Zwicky 397.014 for the sole reason that it is located less than 1° from Altair, so finding the right field is relatively easy. Successfully observing it, however, is another matter. Adding to the difficulty is a faint field star in contact with the galaxy's western edge. In the 13-inch scope this star made averted vision useless.

Only slightly less challenging is **Zwicky 447.001** in the small constellation Sagitta the Arrow. At magnitude 15.3 this galaxy is not an easy mark. If you do see it, you'll be in a very select group of observers who have spotted a galaxy in Sagitta. In the 13-inch this faint spiral was barely visible in the midst of a tangle of field stars, lying between two faint stars aligned north-south.

Some brighter objects can be found farther north in Vulpecula. **NGC 6921** is an edge-on Sa galaxy lying 2° southwest of the open cluster **NGC 6940**. In the 13-inch scope it was a small, high surface brightness object surrounded by faint field





Barred spiral NGC 6951 glows at 11th magnitude and spans nearly 4' across. Official U.S. Naval Observatory photograph. Opposite page: Challenging NGC 185, a satellite of the great spiral M31, is a barely-visible smudge in small scopes. Photo by Kim Zussman (Modified 11-inch f/10 SCT, hypered Tech Pan film, 100-minute exposure).

stars. A somewhat brighter object is **NGC 7052** in the western part of the constellation. This galaxy appeared slightly elongated in the 13-inch and showed a high surface brightness. A 10th-magnitude star lies just off to the east. Only eleven and a half minutes in right ascension farther west is **NGC 7080**, which appeared noticeably fainter than NGC 7052 in surface brightness. A faint star is nearly in contact to the east; another lies to the northeast.

Next it's on to Cygnus and a look at the delicate filaments of the Veil Nebula. Less than 2° southwest of the Veil's brightest segment, NGC 6992-5, is **NGC 7013**, an elongated, 13th-magnitude spiral. In the 13-inch this galaxy was slightly elongated and showed a high surface brightness. A 10th-magnitude star lies close to the north.

From here we cross the galactic equator for a couple of non-NGC objects nestled in the rich Cygnus starfields. A dark sky and high power are essential to discern **MCG +07-41-001**. This tiny elliptical is surrounded by bright field stars. Moving southwest toward the Lyra border we

come to **IC 1302**, a 14th-magnitude spiral. This galaxy was seen in the 13-inch scope amidst a rich starfield. At 120x it was indistinguishable from the scores of faint stars surrounding it. Moving up to 214x, it appeared as a small round object that was only slightly substellar in surface brightness.

I'm sure you have seen M57, the famous Ring Nebula. You may have even seen the planetary's elusive central star. But I doubt that you have seen **IC 1296**, a small barred spiral glowing at magnitude 15.6 that lies in the same telescopic field. Having failed with scopes up to 20 inches in aperture, I think the number of people who have seen this galaxy is small. I'll keep trying, though.

Several faint galaxies surround brilliant blue-white Vega, the brightest of which is **UGC 11281** at magnitude 14.9. In my 10-inch scope high power was necessary to cut down on the glare from Vega. The galaxy appeared as a faint, elongated patch seen only with averted vision.

Now that I've mentioned galaxies near Vega and Altair, what about the remaining star in

the Summer Triangle?

Unfortunately, galaxies near Deneb are completely blotted out by the thick dust clouds in that area. In Lyra, however, you can start by finding the globular cluster M56. About 20' northeast is the 14th-magnitude galaxy **UGC 11428**. This Sc galaxy required averted vision to be seen in the 13-inch scope, showing up as a small, round patch at 214x. **NGC 6792** is a much easier target, a 13th-magnitude spiral visible in the 13-inch scope just southeast of a 10th-magnitude star. This galaxy appeared slightly elongated with a bright core gradually fading out to the edges.

Now move back to the star 16 Cygni. Just north of this star in the same field is **UGC 11465**. This object can be found lying about halfway between 9th- and 10th-magnitude stars. The galaxy's surface brightness is quite high and is rather easy for a non-NGC object. Let the sky drift through your field of view for three minutes and the famous planetary NGC 6826 will be visible. Moving north a few degrees we find **NGC 6824**. This galaxy was easy in the 13-inch scope, showing up

as a small, round patch with a fairly high surface brightness lying within a triangle of 12th- and 13th-magnitude stars.

Smack on the Cygnus-Cepheus border lies **NGC 6946**, the most-observed galaxy in this part of the sky. With the 13-inch at 120x it was a large, hazy, low surface brightness oval. At 214x a small nucleus was visible but the rest of the galaxy had virtually disappeared into the sky background. Several supernovae have been recorded in this galaxy in recent decades, but without a detailed chart the scores of faint field stars make identifying a supernova in this galaxy difficult. About 6° north in Cepheus is **NGC 6951**. This is a nice edge-on spiral showing a bright core and fainter extensions when viewed in the 13-inch scope. An 11th-magnitude star lies close to the east.

Lacerta the Lizard is a small constellation lying close to the plane of the Milky Way, yet it offers a few nice galaxies and one unusual extragalactic object. The open cluster NGC 7209 is a good place to start, since less than a degree northeast is **UGC 11909**. In the 13-







Cassiopeia's NGC 147 is even more challenging than its neighbor NGC 185. Photo by Harvey Freed (10-inch f/6.3 SCT, hypered Tech Pan film, 60-minute exposure). Opposite page: Also in Cassiopeia, tightly-wound spiral NGC 278 has a high surface brightness. Photo by Kim Zussman (Modified 11-inch f/10 SCT, hypered Tech Pan film, 60-minute exposure).

inch scope high power was necessary to detect a faint streak of light extending south of a 10th-magnitude double star. With a large scope this edge-on spindle should be an interesting sight. Moving southwest we find **NGC 7231**, a small, round object with a high surface brightness in the 13-inch scope lying just north of two 10th-magnitude stars.

About 4° south is **NGC 7223**, which appeared pretty faint in the 13-inch scope. A 12th-magnitude star was in contact on the galaxy's eastern edge. The mysterious variable object **BL Lacertae** lies about 2° northwest of this galaxy. Originally thought to be a variable star, BL Lac's extragalactic nature wasn't suspected until after the discovery of quasars about thirty years later. Subsequently, BL Lac lent its name to a whole new class of objects. Its magnitude varies from 12.0 to 15.5, allowing

owners of large scopes to follow its rapid and unpredictable fluctuations. Since its appearance is completely stellar, a finder chart is necessary to locate BL Lac. There is one on page 214 of Volume 4 of the Webb Society *Deep Sky Observer's Handbook*. BL Lac is also plotted as "2200+420" on page 87 of Volume 1 of *Uranometria 2000.0*.

The last constellation of the summer Milky Way is the "lazy W" of Cassiopeia. Known for her dozens of fine open clusters, the Queen also contains some interesting galaxies, most of them members of the Local Group. One such object is the little observed **IC 10**. Lying only 4° from the plane of the Milky Way, only the bright nuclear region manages to shine through the intervening dust clouds. With the 13-inch this galaxy's nuclear region appeared small, round, and faint. An 11th-magnitude star was close

to the west. This galaxy would be quite a sight if it was located far from the galactic plane.

The same can be said for **Maffei 1**, which lies south of **IC 1805**, a large faint nebula in the southeastern part of Cassiopeia. Even though I know exactly where to look, I failed to find this object with the 13-inch scope. Only the nucleus shows up on the red *POSS* plates. Visually it is extremely faint and quite small, lying inside a triangle of faint field stars. Can you spot it?

Two companion galaxies to **M31** can be found within the borders of Cassiopeia, and fortunately they were visible in the 13-inch scope. The first is challenging **NGC 147**, a low surface brightness elliptical with a stellar nucleus. Sweeping to the east brings in **NGC 185**, a large oval haze with a noticeably higher surface brightness than **NGC 147**. Not far off to the east-southeast is **NGC 278**. An

8th-magnitude star dominates the field of view, but this little elliptical shows up pretty well. Long-exposure photos of this galaxy show an intricate pattern of dust lanes that give it the appearance of a spiral.

The galaxies included in this survey range from the relatively bright to the extremely faint, from members of the Local Group out to the realm of the quasars. I hope I've mentioned plenty of objects that you've never heard of and that you are able to successfully observe. It is a rewarding experience to push your eyes and telescope to the limit and see a faint, obscure object that few people have ever seen. Good hunting!

Ernie Ostuno is an active galaxy observer from Cheshire, Connecticut. His last article was "Galaxies near the Winter Milky Way" in the Winter 1989/1990 issue.

The Search for Supernovae

by Steve Lucas

In the year 1006 and then again in 1054, ancient astronomers observed an extra bright star in the evening skies. At the time followers of the heavens were mystified. Could it be a sign from the gods? How could a new star shine in an otherwise unchanging background of stellar beacons? We now know that these apparitions resulted from supernova explosions, one of the most violent and glorious events in the universe.

The energy output of a supernova explosion approximates a simultaneous release of one hundred billion, billion, billion one-megaton hydrogen bombs. The peak luminosity of a Type II supernova is typically 10^{41} watts, which rivals the output of a small galaxy. The total radiated power is equal to 10^{41} joules, which is comparable to the total energy radiated by the Sun in 15 million years. Type I supernovae are even more energetic.

Over the past four years I've organized and operated a modestly successful search for these extragalactic phenomena. Our group is called **SUNSEARCH** and it contains some of the most astute amateur astronomers in the country. Our first success was the confirmation of supernova 1987L in the galaxy NGC 2336 in August 1987. (See *Astrophysics and Space Science* 150:267 [1988].)

A supernova is a rare event. Only slightly over 600 have been seen in the last century. Only by monitoring great numbers of galaxies can you achieve a steady rate of supernova discoveries, and even then the frequency is not very great. Certain galaxies are relatively pro-

lific producers of supernovae. Among those that have produced supernovae every ten to fifteen years are M83, M100, and NGC 6946. It appears, oddly enough, that supernovae occur most frequently in late-type, face-on spirals.

Recently amateurs have become increasingly involved with supernova searches. Visual discoveries by John Bennett, Gus Johnson, Kaori Ikeya, and Dana Patchick in 1968, 1979, 1984, and 1987 demonstrate the possibilities. Between 1980 and April 1989 the Australian amateur Robert O. Evans discovered eighteen supernovae and codiscovered two others. Evans achieved his record through an organized approach to observation, assisted by the development of unique observing aids. Detecting a supernova is a formidable challenge, but if you are willing to search carefully for considerable periods of time, it is quite possible — even likely — that you will discover a supernova.

At this point you might question the purpose of supernova searching. The question deserves a thoughtful answer. Apart from certain spectral and photometric features that define at least two distinct types of supernovae, almost nothing is known about these stars. Any survey that improves coverage or expedites the announcement of discoveries will help astronomers understand this crucial stage in stellar evolution. This extends to well prepared amateur efforts, especially with the consideration that surveillance at professional facilities is neither infallible nor comprehensive. Visual searching is a valid scientific pursuit to the extent

that it is pursued systematically.

Since 1937, when Fritz Zwicky proved the existence of supernovae, Schmidt cameras and blink comparators have been the preferred tools for supernova discoveries. Schmidt surveys have detected virtually all of the known supernovae with a minority of objects found via other means.

Since the late 1960s unsuccessful efforts have been made to create automated telescopes that compare the observed appearance of galaxies' foreground starfields with standard starfields retained in a computer's memory. A variety of problems slow the work. Chief among these is the development of program logic that can cope with the fields of galaxies and the variable conditions of the night sky.

It is probably true that the role of visual observing will be diminished when automatic search devices are perfected and in regular use. The expected capabilities of these systems suggest obsolescence for present methods. However, this is not yet the case and problems unique to computer applications and photoelectric photometry may cause the technique to be an alternative rather than an absolute.

A successful visual search depends on persistence, methodology, charts, and equipment. It should be no surprise that motivation is also an essential ingredient in this kind of undertaking. Probably the greatest obstacle to supernova hunting has been the feeling that it is nearly impossible to find one, that it is like finding a needle in a haystack. Successful supernova watchers like Robert

Evans know that this isn't true. Persistence is the key to success.

The normal method of searching for any rarity is to approach its known sources as frequently as possible. In the case of supernovae, this means monitoring a large sample of galaxies. Schmidt surveys tend to concentrate on clusters of galaxies, while automated searches attempt to cover thousands of galaxies. The visual observer may also take a volume-oriented approach as Evans did. His collection of references spans about 4,000 galaxies, and his observing technique causes him to briefly view scores of galaxies in a few hours. He once surveyed about 400 objects in an eight-hour period on one night. Remarkably, refraining from the use of maps, photographs, or lights at the telescope, Evans relies upon his recollection of the location and appearance of galaxies.

Supernova searching also demands a lot of a person's individual circumstances. Few amateurs possess rural backyard observing sites along with sufficient free time to sustain an effort like Evans'. If monitoring a large number of galaxies is impractical, how can a small number be organized into a useful plan? Some galaxies have intrinsic properties that are related to the observed rate of occurrence of supernovae. Specifically, face-on, overluminous, late-type spirals have a frequency much greater than

Supernova 1989B in M66 shines as bright as the galaxy's center in this photo by Lynn Carroll. The photo was made on February 27, 1989.



Resources for Supernova Searching

by Robert O. Evans, as told to John W. Griese III

The gentle art of hunting for supernovae in other galaxies places many different requirements on an observer. When an amateur astronomer takes up this kind of observing, he or she will need a telescope of sufficient aperture and of a design that will allow observations of many galaxies in quick succession. In addition, regular use of a dark observing site, sufficient charts and photographs of galaxies for checking suspected supernovae, and a support network that can reliably and speedily verify any supernova are essential requirements.

Although some amateurs will try to search with electronic detectors that use computers to identify any new objects, and others may try to hunt for supernovae by taking photographs, most amateurs entering this field will do their searching visually. Thankfully, the situation is rapidly developing where visual observers need't face the enormous problems that had to be faced by those who tried to do this work some years ago. For amateur supernova hunters in years gone by, the greatest difficulties arose in the area of resources: obtaining charts or photos of galaxies that could be related to what appeared in the telescope and that showed enough detail of things that might be mistaken for a supernova.

When I began hunting supernovae in the late 1950s, few photos of galaxies had been published and many of these were not suitable for my use. The *Palomar Observatory Sky Survey* had only just been produced, and it was very expensive for an amateur. Sets in observatories and tertiary institutions were closely guarded. No charts of galaxies existed at all and there was no Schmidt survey available for much of the southern sky.

It has always been a problem for a visual observer to make his own galaxy charts at the eyepiece. The geometry of the starfields tends to be rubbery, often rubbery enough to be misleading next time an observation of that galaxy is made.

Repeated observations of a galaxy under varying seeing conditions tend to reveal an increasing number of faint stars and galaxy details as experience of viewing that galaxy increases. With only rough charts of galaxy fields, how is one to know whether each new star that becomes visible is a supernova or not? After all, some supernovae do appear at or near the telescope

limit in this way. How is one to recognize them?

The last decade has seen the appearance of several kinds of useful resources for observing other galaxies. There have been a number of modest collections of amateur photographs of galaxies published for use in supernova hunting. The key word to remember about these collections is that they are "modest." It will soon be necessary for the observer to spread his wings further than such publications will allow. Also, it is often hard to reproduce these photos so that they show the nucleus in good detail. It is often hard to use these photos to tell whether a star that can be seen embedded in the nucleus of the galaxy is represented in the photo or not.

Several supernova hunting groups are now producing their own charts based on photographs made by members of the group. In some cases these charts are drawn to show visual magnitudes, while others merely reproduce the photographic magnitude according to whatever emulsion was used. These charts are a great improvement on what existed in the 1950s, but they are still far from perfect.

Probably the best product is the set of 230 finder charts produced by Gregg D. Thompson and James Bryan in *Supernova Search Charts and Handbook* (Cambridge University Press, 1990). These charts cover many galaxies brighter than magnitude 11.9 in both hemispheres. The set provides a good basic resource for any visual supernova hunter using a telescope of 12 inches aperture or less. Nearly all of the supernovae I have discovered appeared in galaxies included in these charts.

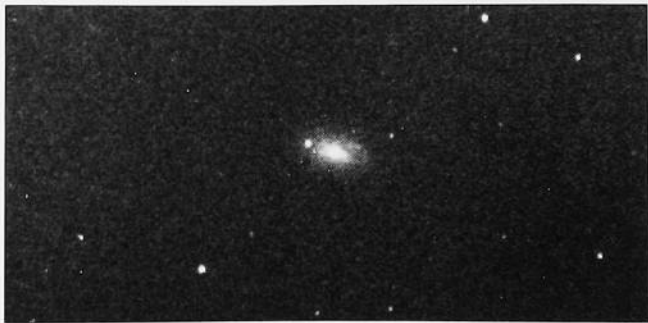
Advanced observers who want to observe a large number of galaxies will require a much greater range of resources. Some of these are yet to be assembled and published or are in the process of being produced. Others can be made by the observer himself. For example, mention has been made by Carl Pennypacker and Richard Muller, leaders of the Berkeley Automatic Supernova Search, that the Berkeley group could at some future point make available the reference pictures of galaxies used by the computer in the automatic search.

Gregg Thompson leads a small group that hopes one day to publish a book containing about a thousand reference photos of galaxies not included in the set of 230 charts, and that were generated from published Schmidt surveys. These photos may not all be as good in quality as one might desire, due to the degrading that necessarily occurs when photos are successively copied. Some of the club groups involved in supernova hunting may expand their library of charts in the future to include some of the fainter galaxies.

One path that more advanced observers can follow, and which I have used extensively, is to make their own photos



In August 1983 a supernova flared in the arms of galaxy M83 and was recorded on August 7 by Jim Barclay (12.5-inch f/6 reflector, VR1000 film, 60-minute exposure).



Jack Newton photographed a supernova in NGC 4414 using a 12.5-inch f/4.3 reflector, 103a-F film, and a 15-minute exposure. The supernova is nearly as bright as the galaxy's core.

of galaxies directly from the Schmidt surveys. This first became possible for me in 1981 when Tom Cragg allowed me to photograph galaxies from the surveys at the Anglo-Australian Observatory near Coonabarabran. I used a friend's 35mm single lens reflex camera with extending rings and an enlarger lens held on with cardboard and tape.

My first attempts were rather poor, as I was very inexperienced in photography and made many mistakes. I used slow fine-grain Agfa or Kodak black-and-white film and developed it all myself using the negatives as the reference pictures. David Malin gave me some tips to help improve the contrast in these pictures, and, as a result, I would underexpose all the photos by one stop and then develop the negatives for twice the normal length of time in my little developing tank. In this way I made a set of slides at a scale smaller than the 67" per millimeter used by the surveys.

This slide set provided me with good reference pictures of about 1,000 galaxies. The slides covered all of the galaxies I had observed at that stage. This served as my basic resource (apart from photocopies of Gregg's charts) for the supernova search with my 10-inch telescope, which lasted to the end of 1985. I also made a number of other slides that had a scale somewhat larger than the surveys and showed all the details that could be seen on the surveys themselves.

By the end of 1985 I began to use a new DS-16 telescope that had been bought by CSIRO, the Australian government research organization, for my use. With this telescope I hoped to increase the number of galaxies I was observing and hopefully find extra supernovae. As a result I began to make a new set of slides using the same enlarger lens but with a new single lens reflex camera and bellows, with proper adapters. This time I used Kodak 2415 film exposed at ASA 100, developed normally. These made a superior set of slides with good contrast that covered several thousand galaxies. The scale of these pictures is about 30 percent larger than the surveys and so reveals all the detail of the originals. I bought the film in bulk quantities, cut it into sections, and loaded it onto cassettes in a darkened room.

By this time the Anglo-Australian Observatory astronomers were allowing me to use their magnificent assemblage of surveys at Epping. At Coonabarabran there had been a proper camera stand, but at Epping I had to make and use my own. Epping is a lot closer to my home, and so every few weeks I would spend a day shooting films in the survey room. The astronomers at the UK Schmidt at Coonabarabran have also kindly allowed me to photograph their survey material, some of which has not been

published. I did not use the glass copies at Epping for fear of causing damage. Although the glass copies are of better quality, the POSS prints and the plastic copies of the southern surveys were sufficient for my purposes.

Of the plastic surveys, the ESO "Quick Blue" survey is best for supernova hunters because the galaxies are not overexposed and foreground star images can be seen right across the front of even the brightest galaxies. The southern "J" survey is much deeper, and as a result the central parts of the brighter galaxy images are usually overexposed and burned out. But the galaxy images are still useful. The red surveys can also be useful in helping to produce reference photos with good detail.

Requests to use such survey materials should only be made by those who are serious about supernova hunting. And it does help if you have already found a supernova. That is evidence that you are serious in your request and that you are worth helping. It is also helpful for observers to work as a group. It is often easier for a club or group to get help from an observatory or university, and the resulting resources can also be pooled. The AAVSO has developed a system for helping its members and has an arrangement with the Harvard Center for Astrophysics that gives members access to a full range of survey materials and permits them to make these resource pictures for themselves.

Another angle is buying prints from the first Palomar survey through the California Institute of Technology bookstore. There are modest minimum order requirements, but the buyer can choose any field he likes. I have not used this resource myself, but a number of amateurs have done so. I have been able also to get some rejected materials from the UK Schmidt Telescope Unit. But this is not an option that would be open generally to others.

Whatever way a supernova hunter overcomes the problem of developing adequate reference resources for checking suspected supernova discoveries or suspicious details about galaxies, it is essential to have these resources. So far as supernova hunting is concerned, it is a waste of time observing a galaxy if you cannot prove that any suspicious looking star is a supernova or not.

I am always glad to hear from serious supernova hunters in need of help in their resource building. Currently I am chairman of the AAVSO Supernova Search Committee, which seeks to provide help in this way or in any other aspect of this kind of observing.

other galaxy types. Between 1976 and 1983 James Bryan of Georgetown, Texas, watched twelve bright spirals that had these qualities. The logic behind a small refined sample has been justified by the appearance of three prominent supernovae in this group during the eight years. These stars included 1979c in M100, discovered by Johnson; 1980k in NGC 6946, photographed by Wild and independently sighted by Bryan; and 1983n, found by Evans.

The matter of charts for star-

fields around galaxies is the most important technical problem for supernova searchers. In the past the only way to obtain these has been to either draw them at the telescope, trace them from photographs, or use photographs as charts. Each option has particular deficiencies. Chart making by observation faces the need to maintain proportion throughout sketched fields, to establish a scale that may not be well served by available telescopes, and to detect faint stars at unknown positions

that may only be seen infrequently under good sky conditions. Few observers can regularly meet these requirements. Tracing photographs is more flexible and practical, but it is limited. Most images have narrow margins that conflict with the relatively wide-angle fields delivered by small telescopes. Most vexing is the tendency of photographs to "burn-out" bright nuclear regions and stellar associations, thus obscuring superimposed field stars. These same problems make

using most photographs as charts unsatisfactory.

A solution to the lack of charts has been developed by James Bryan and Gregg Thompson. Their book, *Supernova Search Charts and Observing Handbook*, published by Cambridge University Press this year, contains a collection of 237 charts depicting 342 galaxies. The material is based on tracings of photographic enlargements taken from Schmidt camera sky surveys. The tracings are adjusted at the tele-



The brightest supernova in recent times erupted in the Large Magellanic Cloud in 1987. Chris Floyd recorded supernova 1987A (right, above center) on February 3, 1987 with a 10-inch f/4.5 reflector. Opposite page: In 1986 observers witnessed the bright supernova in NGC 5128, the enigmatic galaxy known as Centaurus A. Jim Riffle recorded the guest star on May 12, 1986, using a 12-inch f/5 Astromak, hypered Tech Pan film, and a 60-minute exposure.

scope to relieve disparities between photographic recordings and visual impressions. "We rely on controlled scale and proportion available in photography, but alter the known starfield by observation," said Bryan. Concern for details in the preparation of this material should logically produce results with special advantages.

However, it is impossible to ignore the fact that more than two-thirds of Evans' charts are 35mm photographic slide enlargements from southern

Schmidt surveys. Many of these have overexposure problems. Evidently he finds no serious limitation in this feature. Evans' first discoveries came when using Thompson's chart drafts. These, however, were too few in number (approximately 200) to support the scale of activity he currently requires.

The type and size of telescope required for supernova searching depends on whether the user intends to draw charts. If the answer is yes, large scopes are much better than

small ones. Small instruments lead to too much uncertainty in deciphering a starfield. Therefore an aperture of 8 inches is the smallest you should use. At this aperture, however, observers have serious constraints placed upon their work. Bob Evans recommends a 10-inch short-focus reflector as a practical compromise between convenient physical size and sufficient aperture.

Extragalactic supernovae are faint stars, the brightest glowing at 11th or 12th magnitude.

While the owner of an 8-inch scope may hunt with confidence, his options are limited. Compare the approximate extreme limit of this telescope at 14.6 magnitude with a rough average supernova maximum of 15.0 magnitude. Since searching occurs at the extreme limit and an observer can expect to observe stars of 13.5 magnitude, large scopes offer an advantage. Their chief value comes in eliminating uncertainty in potential sightings.

Most of Evans' discoveries





The big supernova event of the late 1970s occurred in the galaxy M100 in Coma Berenices. Ken Johnson produced this photograph of the supernova, designated 1979C, on April 23, 1979.

are not fainter than 14th magnitude. This is an effect of his procedure of quickly scanning each scene with the expectation that any irregularity in appearance will be discernable. He acknowledges that the technique could, and in one case did, cause him to fail to detect a faintly visible supernova. But upon considering Evans' discoveries, several professional astronomers have restrained their comments on the general faintness of supernovae in contrast to amateur capabilities.

Instead they ask how many bright supernovae may be going unseen by Schmidt patrols.

Amateur discoveries have contributed to the resurgence of general interest in supernovae in the past few years. They have contributed to the current flowering in the theoretical analysis of Type I supernovae, led by J. Craig Wheeler and David Branch. Two of these discoveries have led to the realization that there are two completely different classes of supernovae with a Type I light curve. The

new class of objects are now called Type Ib supernovae. Two supernovae (1983n and 1984g) have become the prototype examples of this class.

The two brightest supernovae in recent years, 1983n and 1986g, have also been used as probes of intergalactic space, resulting in the discovery that several clouds of interstellar gas lie between the Milky Way and the Centaurus group of galaxies. Amateurs have also become involved in determining light curves for some of these super-

novae, as there has often been a failure by professionals to do sufficient photometry of these events. An example of this contribution has been the recent supernova in the galaxy M66. With the future growth of backyard telescopes it will soon be possible for amateurs to become more involved in photoelectric photometry of the brighter supernovae, just as amateurs are increasingly monitoring variable stars in this way.

With proper organization amateurs will be able to make a

Supernova Searching in the Big Apple

by Jenny Worsnopp

Supernova searching from New York City is hard work. The problem isn't light pollution, although we've got lots of that. It isn't the traffic, which makes leaving the city an ordeal all by itself. It isn't even the roads, which are in such poor condition that if you try to go faster than 40 miles per hour your fillings fall out of your mouth.

The trouble is the parking. Anyone who is familiar with alternate side of the street parking knows what a nightmare it can be. You're always one step ahead of the sheriff.

Every day all the cars on my block have to be moved from one side of the street to the other by 8 a.m. If they aren't, they get a \$40 ticket or get towed. We can officially move them at 11 a.m. Of course we all line up at 10:30, sitting in our cars waiting for 11 a.m. If you leave your car before 11 a.m., you risk a ticket. I've seen cops write out tickets at 10:58.

When I leave at night to go observing, I'm not just driving out of the city, I'm giving up my parking space. No big deal? It's when I get back that the problems start. Because I live in an apartment building I have to carry my scope and accessories down six flights of stairs. The scope is a 13-inch Serrurier truss model that breaks down into pieces. With the scope, my binocs and notebook, maps and charts, clothes, boots, music, and food it takes six trips up and down the stairs to load it all into the car. Next comes the crush of traffic on the roads. If I leave at rush hour I creep along at 20 mph until I'm outside of Manhattan.

My observing site is sixty-five miles north of the city. It's a parking lot in a state park. The trip takes ninety minutes, but it's worth it. My telescope shows me stars down to

magnitude 15.3 from the parking lot.

One night my car broke down at the state park. It was one of those First Quarter Moon nights when the Moon sets at 1 a.m. I drove in at 11 p.m., didn't like the view from where I was, and decided to move the car a few feet. I got in, turned the key and it was dead. I didn't want to wake the park manager so I walked a quarter mile down the road to a public phone and called the AAA. They had trouble with the address; it's hard to describe exactly where you are if it's in the middle of a state park.

Then, of course, I had trouble with the guy at the garage, so it took well over an hour before everything was straight and a mechanic was on his way. Thank goodness I had a phone card and a few quarters. The mechanic was a nice guy who told me I had loose wires, which he fixed. He spent the next hour looking through the scope with me.

When he took off it was at 3 a.m. and I had long since run out of energy. I made a couple of observations and called it a night. It wasn't what I had in mind when I schlepped that stuff down the stairs.

I returned extremely late and encountered the usual parking situation. I usually pull up to the building to unload. Then come the six trips up and down the stairs. After I've done that I have to go back to the car and find a parking space. If the universe is kind, I'll get a parking space on the right side of the road. This is something akin to a miracle. The absolute rock-bottom worst is driving around in the early hours looking for any spot at all. Usually I get a spot on the wrong side, but somewhere on my block.

I guess somewhere deep inside I believe that great devotion brings great rewards, and that one of these days a supernova will happen and I'll be there to catch it. If it doesn't, I'm going to be a very disillusioned old lady.



Jack Newton photographed this faint supernova near the center of galaxy NGC 4490 with 16-inch f/5 reflector.



Another Newton photograph, an 18-minute exposure made with a 20-inch f/5 telescope, shows a supernova in galaxy NGC 4753.

major contribution in determining the rate of appearance of supernovae in the various kinds of galaxies. By collating and studying the statistics of negative and positive search observations of many different galaxies over a long period, we can know more clearly the average supernova rate.

The first steps have already been taken in this direction. An article submitted to the *Astrophysical Journal* made a study of about 50,000 visual observations of 1,081 galaxies beginning in 1980 and ending in 1985. A subsample of 709 Shapley-Ames galaxies was used to help create homogeneity. Of the twenty-nine supernovae discovered during the five-year period, eleven were discovered visually and four others were seen independently, resulting in a total of fifteen events falling within the scope of the search. Estimates of the supernova rate were made on this basis by Sidney van den Bergh in 1987.

This study has recently been

updated to include 855 Shapley-Ames galaxies extending the original study to October 31, 1988, during which time nine more events were recorded, of which five discoveries and two independent discoveries were added to the visual totals.

The detection of these enormous stellar events represents one of the final bastions of scientific discovery left open to the amateur. Careful scrutiny is the price that has to be paid for such a project. Our group, SUNSEARCH, welcomes in-

quiries for involvement from non-members. Supernova searching certainly isn't the easiest area to tackle, but it is rewarding to know that every time a galaxy is observed, the potential for discovery is present.

Steve H. Lucas, the founder of SUNSEARCH, is an extremely active observer and has written for *ASTRONOMY* magazine.

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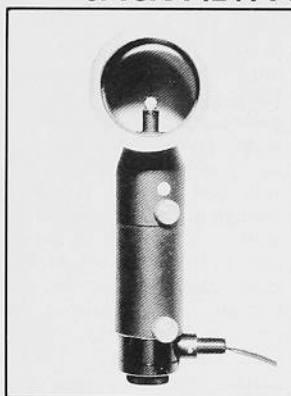
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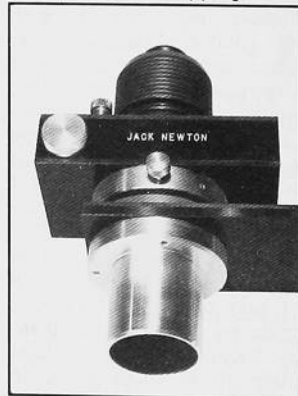
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Deep Sky Reports

In Search of the Dragon

by Dennis Casper

Where are the interesting galaxies in the summer sky? I asked myself this question as I stared up at an unusually clear July sky. I did not know the answer, so I started looking through my star charts. Many of the galaxies in *Uranometria 2000.0* are faint and small, and I did not want to spend the whole night trying to find 15th-magnitude galaxies. I have nothing against the faint stuff, but tonight I wanted to observe some galaxies that would show some detail.

Finally I ran across an unusually large galaxy I had never observed that was well placed for viewing. The galaxy was just above the bowl of the Big Dipper in Draco. The galaxy was NGC 4236. It was a large, elongated oval of 11th magnitude. The galaxy had a large, bright nuclear region surrounded by a very diffuse outer glow. It reminded me of a much smaller, fainter version of M31.

After sketching that galaxy I returned home at about 2:30 a.m., grumbling about only doing three drawings in five hours. I was determined to plan my next observing session better and not waste another excellent night.

The next day I wondered how many more bright, large, fascinating galaxies I have neglected in Draco. I looked in *Burnham's Celestial Handbook* under Draco and found that the constellation was loaded with bright galaxies. I then set out to observe and draw every object in *Burnham's* listed under the Dragon, and maybe a few more.

I conducted my search from my observatory outside of Sterling, Illinois, in Emerson. I used a 13.1-inch f/4.5 reflector for all my observations. This survey of Draco began in July 1989 and ended in August. In all I have observed 46 objects, all galaxies except for one planetary nebula. These objects include all of those listed in *Burnham's* plus other fainter galaxies shown in *Uranometria 2000.0*. *Uranometria* lists over 300 objects in Draco, most of them faint galaxies. There are

also a few planetary nebula. In my search I concentrated on the brighter objects that would show some detail in medium-size telescopes. I added a few faint galaxy groups for those who want to go deep into the constellation.

After that first night when I observed NGC 4236, I began the survey at the tail of the dragon. The first object observed was **NGC 3147**. I found this galaxy by pointing my telescope at the obvious asterism northwest of M81 and star hopping into Draco. NGC 3147 is easily found next to a 6th-magnitude star. NGC 3147 appeared as a bright medium-size, slightly oval galaxy. The nucleus of the galaxy was round and appeared very prominent. The outer regions of the galaxy were much more diffuse.

The next galaxy was the 13th-magnitude spiral **NGC 3403**. This galaxy is pretty easy to find but it caused me the most trouble of all the galaxies. How could a 13th-magnitude galaxy give a 13.1-inch telescope problems? When I tried to observe this galaxy in late July and August it was low enough to cause my observatory wall to block half of my aperture. In the first week of August cool, clear air moved out of Canada and it allowed me to observe this galaxy with a 6-inch aperture. NGC 3403 is a small, pretty faint oval galaxy. It has a slightly brighter oval nucleus that brightens to a small core in its center. This galaxy is elongated about east to west.

NGC 3348 is a galaxy about a degree south of NGC 3403. NGC 3348 is easily found about three minutes west of a 10th-magnitude field star. This galaxy lies on the Draco-Ursa Major border. It is listed in *Burnham's* under Ursa Major but, because it is situated right on the border, it is worth mentioning in this survey of Draco. NGC 3348 appeared as a very small, round, slightly oval galaxy about 35" in extent. NGC 3348 is pretty bright, about 12.7 magnitude. It has a very tiny bright nucleus. There is a star of



Galaxy NGC 3735 sketched at 234x. All sketches in this article were made by Dennis Casper with a 13.1-inch f/4.5 reflector.



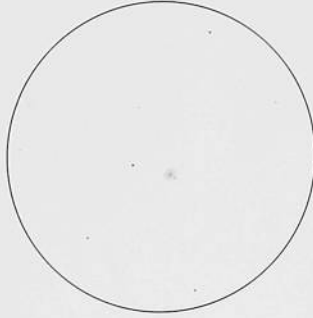
Similar in appearance to NGC 3735 is the edge-on spiral NGC 5907, here sketched at 143x.



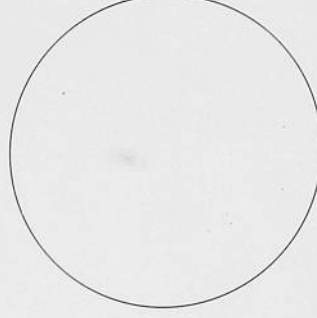
NGC 3147 sketched at 234x.



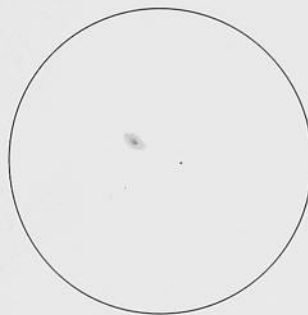
NGC 3329 sketched at 234x.



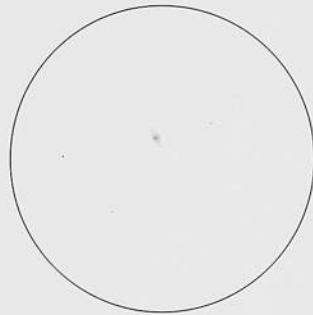
NGC 3348 sketched at 234x.



NGC 3403 sketched at 234x.



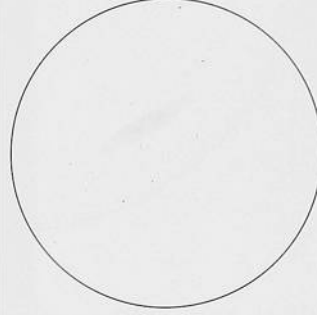
NGC 4125 sketched at 234x.



NGC 4128 sketched at 234x.



NGC 4133 sketched at 234x.



NGC 4236 sketched at 75x.

about 12th-magnitude approximately 15" to the east of the nucleus.

Moving toward the north pole **NGC 3329** is easily found in a keystone asterism one degree north of a 5th-magnitude field star. NGC 3329 is a small, moderately bright galaxy. It seems to have three different zones of brightness. There is a small, bright core surrounded by the nucleus which is surrounded by a faint outer glow. The galaxy is elongated north-south.

There are several other galaxies in the neighborhood of NGC 3147 but most are very faint. I spent some time attempting to observe some of these galaxies but I did not succeed, so I moved on to bigger and brighter galaxies. If you have access to a large telescope and want to look for NGC 3147's neighbors, you will find them on chart 8 of *Uranometria 2000.0*.

The next area to explore in Draco is centered on the large spiral **NGC 4236**. When observing NGC 4236, use low power. I found that if there is any haze it makes this low surface brightness galaxy almost disappear. About a degree southwest of NGC 4236 lies **NGC 4128**. This galaxy is small, pretty bright, and oval. It has a bright, round nucleus. The outer regions of the galaxy look like triangular projections from the nucleus. This galaxy is elon-

gated west to east. Unlike NGC 4236, low surface brightness is no problem with NGC 4128. *Uranometria* shows a companion to NGC 4128, **NGC 4128A**. I attempted to see NGC 4128A and I thought I saw something, but I was not sure enough to include it in my drawing. If you have a large telescope or if you have a normal scope and a great desert or mountain observing site, try to see this galaxy and let me know if you succeed.

About three and a half degrees south of NGC 4236 lies the beautiful edge-on spiral **NGC 4256**. This galaxy is medium in size and oriented edge-on. The oval nuclear bulge is very apparent. This bulge is by far the brightest part of the galaxy. The spiral arms taper into needle-thin points. The most southerly arm appears to be the longest and brightest of the two. A bright line of nebulosity runs through the middle of the galaxy. NGC 4256 is elongated approximately northwest to southeast. This galaxy seems brighter than *Burnham's* magnitude of 13.

Move your telescope about half a degree west and slightly north to a 7th-magnitude star and follow a line of three 8th-magnitude stars south to **NGC 4125**. This galaxy is small and has a high surface brightness. NGC 4125 has an oval shape and an extremely bright, elon-

gated nucleus. There is a pretty bright field star to the east. NGC 4125 is elongated about east to west. Point your telescope about a degree north of Lambda Draconis and you will find **NGC 3735**, a nice edge-on galaxy. This galaxy is medium in size and pretty bright. There is a brighter central bulge with a bright oval at its center. This galaxy is brighter in a line through the middle. It has very faint spiral arms and is elongated southwest to northeast. NGC 3735 is similar to NGC 4256. The difference is that NGC 3735 has a brighter center and seems a little less edge-on.

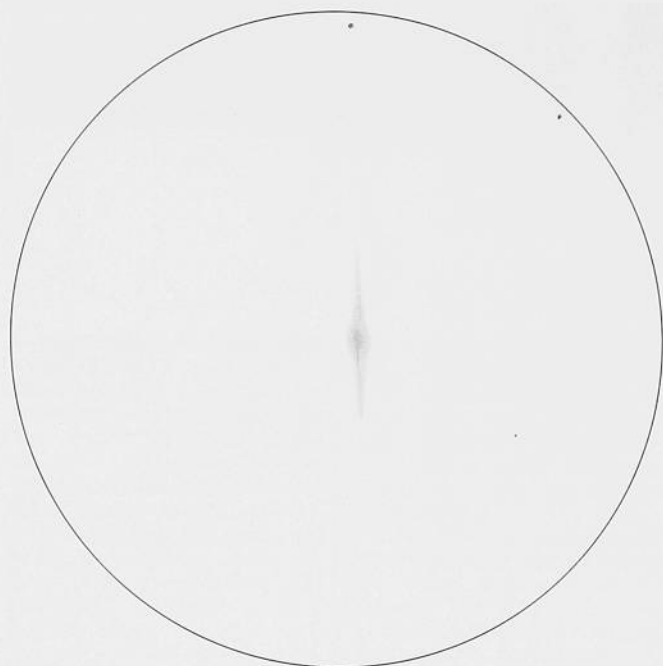
Move back to NGC 4236 and find an L-shaped asterism to its north. Halfway between the top of the "L" and a row of three bright stars to the east is **NGC 4750**. This galaxy is a medium-size oval glowing at about 12th magnitude. NGC 4750 has a mottled disk that is slightly brighter toward the center. It is elongated northeast to southwest. About a degree and a half northwest of NGC 4750 is **NGC 4589**, a small elliptical galaxy. This galaxy is slightly oval in shape and has a bright center.

A small group of three galaxies lies 1.5° northwest of NGC 4589 and is easy to find adjacent to a 5th-magnitude star. Composed of **NGC 4319**, **NGC 4291**, and **NGC 4386**, the group

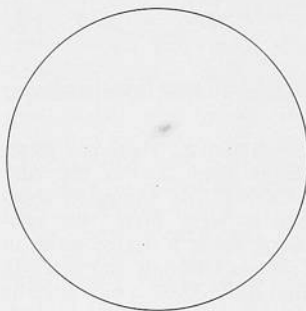
is challenging but visible in small scopes. NGC 4291 is the brightest of the three galaxies. It is small, has an extremely bright oval center, and is oriented southwest-northeast. I sketched this galaxy in the same high-power field as its fainter companion NGC 4319, which appears as a small oval glow. NGC 4319 appears slightly mottled and has a bright, round center. The galaxy is elongated west-southwest to east-northeast.

The last member of this little group, NGC 4386, was drawn separately from the other two galaxies. NGC 4386 is a small, oval galaxy with a bright center, elongated southwest-northeast. *Burnham* suggests NGC 4386's dimensions are 42" by 18", but this seems too small. One degree southwest of this triangle of galaxies is **NGC 4133**. This elliptical galaxy is a pretty faint oval. It has a bright oval center that gradually fades and is elongated east-west.

Now move your scope up to Iota Draconis. This star lies between two loose conglomerations of galaxies. About 3° south and 1° west of Iota is one of the most beautiful edge-on galaxies in the sky, **NGC 5907**. This galaxy is a long, thin smoky streak bright enough to be observed with almost any telescope. It has only a slight nuclear bulge, which is brighter



The edge-on galaxy NGC 4256 appears as a glistening sliver in small scopes. This sketch was made at 234x. Right: NGC 4386 consists of a bright ring of material surrounded by a faint halo, as shown in this 234x sketch.



NGC 4291 (left) and NGC 4319 are elliptical galaxies easily visible in this 234x sketch. The faint quasar Markarian 205 lies adjacent to NGC 4319, but is not visible in this rendering. Left: NGC 4589 sketched at 234x.



than the rest of the galaxy. With averted vision the regions away from the nucleus transform from a faint streak into a bright, mottled glow. The western side of the nucleus is the brightest. I faintly detected a very thin, off-center dust lane cutting through the eastern side of the nucleus. This galaxy is worth a long look and a detailed drawing to bring out all of its hidden details.

After NGC 5907, move your telescope 1° northwest and you'll find NGC 5879 lurking just south of a 7th-magnitude star. NGC 5879 is a small, bright, elongated oval galaxy. It has a bright, round nucleus with small spiral arms projecting outward from it. NGC 5879 and NGC 4128 are very similar in appearance, each appearing as edge-on Sa galaxies. After looking at NGC 5879, slew the telescope 1° south and slightly east and you will find M102 (NGC 5866). If you have a large finder you may be able to set the crosshairs right on it. M102 is a small, oval galaxy glowing at 11th magnitude. It has a bright

oval center and an overall high surface brightness. This galaxy is located between two field stars of about 10.5 magnitude. NGC 5866 is elongated north-east to southwest. *Burnham's* shows a picture of M102 with a thin dust lane. I tried to see it but failed to pick out this feature.

For those who are in the mood to hunt for challenging galaxies, there are four companion galaxies to NGC 5866 shown in *Uranometria 2000.0*. NGC 5866A was the first of these companions to be discovered. It appeared as a tiny, faint oval of around 14th magnitude. It was definitely brighter toward the center. There are two other faint galaxies to the south of NGC 5866. NGC 5862 and NGC 5870 form a pair of faint galaxies at medium powers. Both seem to be between magnitude 13.5 and 14. NGC 5862 appears as a slightly oval disk that is a little brighter toward its center. NGC 5870 is an elongated, oval-shaped galaxy with a brighter, oval center. The last of these faint galaxies lies three-

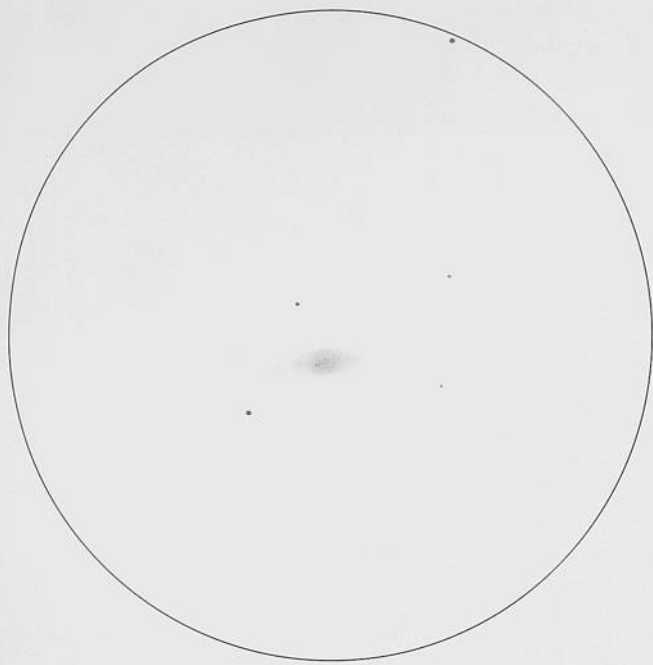
fourths of a degree east of M102. It is designated NGC 5866B. This little galaxy is a faint round ball of nebulosity lying between two 9th-magnitude stars.

Southeast of NGC 5866B is a nice pair of brighter galaxies, NGC 5905 and NGC 5908. NGC 5905 appears as a pretty faint, slightly oval glow with fairly even brightness throughout. *Burnham's* lists the size of this galaxy as 4.4' by 3.2', but it appeared smaller to me. This is probably because I only glimpsed the inner regions of this barred spiral. NGC 5908 is yet another edge-on system. It appears as a pretty faint streak with a brighter, oval nuclear bulge.

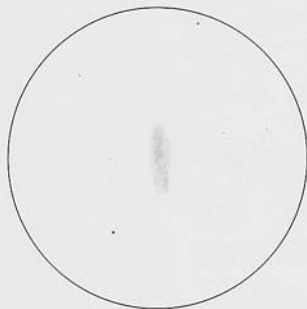
Moving west past M102 toward the bright galaxy NGC 5678, see if you can detect NGC 5779. This galaxy was just visible as a very small oval glow that was slightly brighter toward its center. It is located just north of a 7th-magnitude field star. Starhop a few bright stars west and north and you will find NGC 5678. This gal-

axy is a bright, slightly mottled oval. It is gradually brighter toward the center. Use high power on this one because it is small and has a high surface brightness.

Point your telescope one-third of the way from Iota to Theta Draconis and you will be on a beautiful little group of galaxies dominated by the Sb galaxy NGC 5985. The group also contains a small elliptical and an edge-on galaxy. These galaxies lie in the same high-power field of view. NGC 5985 is a medium-size galaxy glowing at 12th magnitude. It is oval in shape and has a small round nucleus. I failed to glimpse its spiral structure, but with averted vision the disk appeared slightly mottled. This galaxy is elongated about north to south. NGC 5982 is just west of this galaxy. NGC 5982 is oval and has a bright disk that gradually brightens toward the center. On an exceptionally clear night I detected a faint outer glow around this galaxy. On that same night I recorded NGC 5981. This object appears as a



M102 (NGC 5866) is a bright, oval glow in nearly any telescope. This sketch was made at 234x. Right: NGC 6503 is large and easily visible in small scopes, and is shown here at 234x.



faint streak even with averted vision. With direct vision its bright oval nucleus is all that is visible. I estimated this galaxy's size as 4'. There are several other galaxies in the immediate area that I tried to see a few times, but I failed to do so.

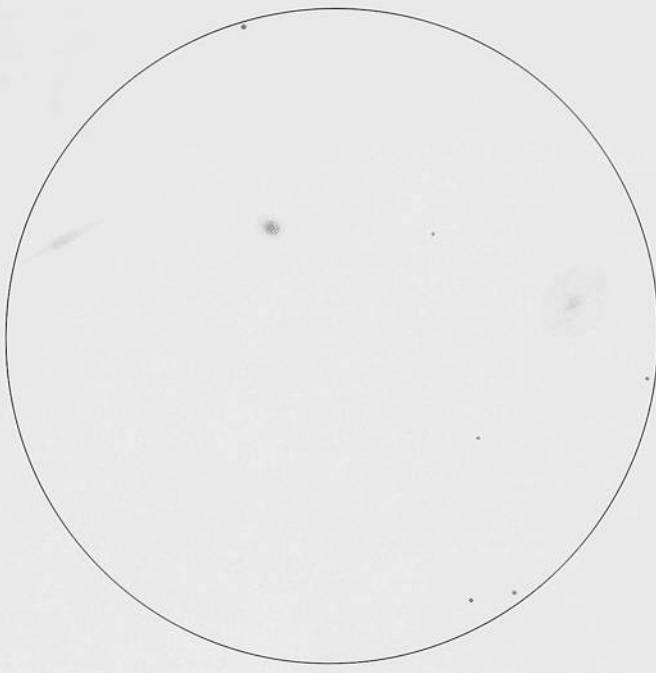
For the next galaxy in this area point your telescope at the 5th-magnitude star forming the apex of an isosceles triangle with Iota and Theta Draconis. Just 30' to the southeast of this star is the highly inclined spiral **NGC 6015**. This is a bright, medium-size galaxy. It has an elongated oval shape with a bright oval nucleus. There is a faint star involved on the northern edge of the galaxy. The outer glow of this galaxy appears slightly mottled. Move the telescope about two degrees to the northwest of the bright star next to NGC 6015 and you will find a right triangle of 7th-magnitude stars. **NGC 5949** is a small, bright, oval galaxy with a brighter oval nucleus. It is elongated almost north to south.

The last area of Draco to cover is centered on the triangu-

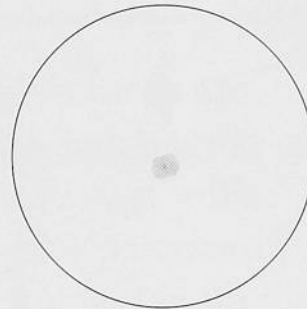
lar asterism formed by the stars Phi, Chi, and Psi Draconis. The brightest galaxy in this area is **NGC 6503**. It is easily found by star hopping south of Psi or north of Omega Draconis. It lies northwest of an 8th-magnitude star. NGC 6503 appears as a medium-size irregular rectangle of nebulosity. It is very bright. Burnham suggests it glows at 11th magnitude, but I think it is brighter. The galaxy is brightest through the middle and has a mottled appearance.

Move your scope 1.5° north of Chi and you will find **NGC 6643**. This galaxy is a beautiful spiral. It is a medium-size oval of about 12th magnitude. NGC 6643 has a bright, oval nucleus. The west and east ends of the galaxy appear wispy, hinting at spiral structure. There are four field stars nearby forming a check mark asterism.

About 3° west and 1° north lies **NGC 6412**. This galaxy appears as a softly glowing oval without detail. NGC 6412 seems fainter than Burnham's magnitude of 12.2, but it still should be a pretty easy target.



Galaxies NGC 5981, NGC 5982, and NGC 5985 (left to right) are visible in the same moderate power field. This sketch shows the view at 143x. Left: Planetary nebula NGC 6543 displays a peculiar structure at high magnification, as shown by this composite drawing.



Use the triangle asterism to point your way to **NGC 6340**. It is at the end of a curve of three 7th-magnitude stars. This is a small, slightly oval galaxy with a pretty bright, round nucleus and mottled outer regions.

Move back to the triangle asterism to hunt for some faint galaxies. **NGC 6434** is located west of Psi Draconis by a 7th-magnitude star. It appears as a small oval with a brighter oval center. I estimated its brightness to be about magnitude 13.3. The size of this object appears to be about 50" by 30". It is elongated west to east. **NGC 6508** is on the other side of Psi Draconis about two-thirds of the way to the 5th-magnitude star 34 Draconis. NGC 6508 is a small, slightly oval galaxy. I estimated it to be about 13.4 magnitude. The size of this object appeared to be about 40" by 30"; it is elongated east-west.

The last group is actually a pair of what looks like interacting galaxies. The largest of the pair is **NGC 6622**. It is a small oval with a large, bright center. This galaxy glows at about

magnitude 13.6 and has a size of approximately 60" by 25". **NGC 6621** is 8' west of NGC 6622. It is tiny, round, and very faint, glowing at magnitude 13.8.

This survey ends at the north ecliptic pole on Draco's most famous member, **NGC 6543**. It is very bright, about 8th magnitude. It has a bright blue central star of about 10th magnitude floating inside the greenish nebulosity. I saw the looping oval rings in the nebula, which often show in photographs. These features are subtle, but can be seen with careful observation. On the southwest side of the nebula one of the rings bulges out. This bulge is fainter than the surrounding nebula. There are slight bulges in the corners of the nebula, giving it a rectangular appearance. The planetary is elongated about north to south. I tried to draw this nebula using 234x and I almost tore a hole in the paper. Unless you can use extremely high power, I think making a detailed diagram is the best way to record this nebula.

Deep Sky Reports

Observing the Great Cygnus Bubble

by Jim Meketa

When I was thirteen years old, I purchased a 6-inch f/8 reflector and a set of the old black-and-white *Skalnate Pleso* charts. It was my first big telescope and my first set of real star charts. I remember poring over each chart as it revealed a sky full of wonder.

One object in particular caught my attention. It was a huge, ghostly circle on Chart V, almost hidden on the edge of the Milky Way in Cygnus. The fragments of the circle, so obviously the remnants of a vast explosion, I soon learned were called the Veil Nebula. Beautiful photographs of it seemed to appear in every astronomy textbook I read.

The skies in Albuquerque in 1960 were still dark, and I searched the Milky Way near 52 Cygni confident I would soon behold the pale streamers in the photographs. But like the equally fascinating Horsehead Nebula, the Veil eluded me time and again. Gradually I came to assume that it was impossibly faint and would be barely visible even in the largest telescope.

Twenty-one years later I found myself in the Davis Mountains of West Texas, with a new 18-inch reflector and dark, clear skies. I watched the Milky Way rise slowly over an eastern horizon that flashed intermittently with distant lightning. Late in the morning I turned to Cygnus. The sky was dark enough that I could see intricate details in the Milky Way, but high humidity and three bright planets degraded sky contrast noticeably. The sky looked dark grey rather than black, and the horizon was clearly visible in all directions.

With fairly low expectations I centered 52 Cygni in the crosshairs of my 4-1/4-inch f/4 finder. At 16x I saw a rich Milky Way field and nothing else. But when I turned to the 18-inch scope at 82x, I was amazed. Extending north and south on both sides of the bright star was an obvious band of milky light. I slewed 52 Cygni out of the field and was shocked again — it was enormous. Without any difficulty I could see streamers extending more

than a 37' field on either side of 52 Cygni. The eyepiece was filled with subtle details that looked very much like the photograph on page 802 of *Burnham's Celestial Handbook*.

After a few moments I moved the telescope east, expecting the other side to jump into view. When it didn't, I was puzzled and returned to the finder. Here NGC 6992 was immediately visible, and so was the reason for its non-appearance in the 18-inch scope. The eastern side is over 2.5° away, almost five eyepiece

should be at its center been found.

In amateur telescopes and on long-exposure photographs the Veil Nebula is broken into a number of discrete pieces that appear to define a rough sphere. Five of these pieces were detected visually by Herschel and were assigned NGC numbers. After very careful searches in Texas and Martha's Vineyard, I was able to locate all five NGC portions.

The easiest part of the nebula for amateurs to locate is NGC 6960. While not the brightest of

ern part was assigned the designation NGC 6992 and the southern part NGC 6995.

The most difficult portions of the nebula are on the north side in the middle. In photographs, the most prominent feature here is dagger shaped. Although it was not assigned an NGC number, I found it to be only moderately difficult to locate and very well defined. At the north end it was at least 35' wide and tapered to a sharp point about a degree to the south. A string of bright telescopic stars runs its length.

The final two parts, NGC 6974 and 6979, were very difficult. On deep photographs these two objects are revealed as a single mass of luminous gas, but visually they appear separate. They are both of extremely low surface brightness. I was able to locate them only after about half an hour of very careful sweeping. The Milky Way here is very rich, and the profusion of background stars tends to obliterate the faint traces of nebulosity.

Without question the Veil Nebula is one of the most challenging and fascinating sights in a large telescope. While parts of it can be seen in finders or even large binoculars, its true glory is revealed only in large instruments. After viewing it or attempting to view it on many separate nights, I can offer the following advice. First, your sky must be very dark and transparent. Unless the Milky Way appears bright and richly detailed to the naked eye, you are likely to have trouble with the Veil.

Second, your optics should be clean and free of dew or condensation, as even the slightest loss of contrast will spoil your view. And finally, use low powers to achieve the largest possible exit pupil. The Veil is very large and dim, so you will need to get as much light to your eye as possible.

The full glory of the Veil Nebula is visible in this photo by Alfred Lilge (4-inch f/6 astrograph, 098-04 film, 75-minute exposure with an orange filter.

The Veil Nebula is wide and curved and every inch is filled with detail: wisps, intertwined streamers, and delicate curtains, all set against a dense background of Milky Way stars.

fields in the 18-inch scope. I realized that I was looking at an object with an entirely different scale than the other objects I had seen that night.

The Veil Nebula was discovered in 1784 by William Herschel with his 18-inch speculum metal reflector. He was able to detect the two brightest portions but it took the invention of astrophotography to reveal the true nature, size, and beauty of this ghostly sphere. While modern photographs and spectroscopic studies demonstrate that the Veil is unquestionably a supernova remnant, exact details about its origin and structure remain elusive. According to Robert Burnham, Jr., the nebula is probably about 1,500 light-years distant, 70 light-years in diameter, and perhaps 40,000 years old. To date, the source of its fluorescence has not been identified, nor has the neutron star pulsar that

the five, NGC 6960 runs directly through the wide 4th-magnitude double star 52 Cygni, making it the best place to start when studying the Veil. In my 18-inch f/4.5 Newtonian, NGC 6960 is very narrow and twisted and extends approximately 40' north of 52 Cygni and about 50' south. The northern portion is narrower and consequently brighter.

From NGC 6960 it is probably best to slew 2.5° east across the open middle to the largest and brightest portion, NGC 6992 and 6995. This side of the nebula is easily visible even in small instruments and stretches for nearly a full 2° in my 18-inch scope. It is wide and curved and every inch is filled with detail: wisps, intertwined streamers, and delicate curtains, all set against a dense background of Milky Way stars. While obviously a single object in my 18-inch scope, the north-



Deep Sky Reports

Summer's Challenging Deep-Sky Objects

by Phil Harrington

There's no doubt about it, planetary nebulae are among the most challenging objects in the sky to observe. Typically exhibiting tiny disks no more than a few arcseconds across, planetaries easily disguise themselves as "just another star" among a myriad of surroundings points of light.

Ironically, their humble appearance helps to maintain a relatively high surface brightness, which make planetaries ideal for study by urban and suburban enthusiasts. Even when the faint shimmers of more diffuse objects can not pierce poorer sky conditions, the nearly stellar disks of planetary nebulae come shining through.

Frequently, a planetary's existence is evidenced only after its feeble light is viewed through a slitless spectroscope

or a prism held at the eyepiece by the observer. While starlight breaks into a full spectrum of color, the light from the planetary only shines at very discreet wavelengths (such as hydrogen-alpha and oxygen-III), causing it to look like a single point among the stellar spectra.

Another way to isolate a small planetary is to alternately search the suspected field with and without a nebula filter. By changing between a filtered and unfiltered view the planetary will appear to "blink" while the stars remain constant.

Last summer I offered a selection of four planetaries for you to try your luck with. Were you successful? In keeping with that motif here is another set of planetary nebulae to challenge your observing skills. They all await you tonight.

Giant binoculars and 2- to 3-

inch scopes: NGC 6543

Stats: R.A. 17h 58.6m, Dec.

+66° 38' Constellation: Draco

Magnitude: 8.8 Size: 18"

While most summer planetary nebulae are crowded into the southern sky near the center of the Milky Way, NGC 6543 stands as the lone bright planetary in the northern part of the seasonal heavens. Nicknamed the "Cat-Eye Nebula" for its unusual structure and greenish color, it is about halfway between the stars Delta and Zeta Draconis, to the north of the dragon's head.

Through small telescopes and large binoculars, the colorful tint of the Cat-Eye's bright disk easily sets it apart from stars. A 3-inch telescope at about 100x begins to resolve the planetary's true non-stellar nature and offers the first glimpse of its 11th-magnitude central star.

Photographs reveal a fascinating form to the Cat-Eye, with a pair of opposing gaseous loops intertwined around the star as well as a very faint outer shell of nebulous debris about 4' in diameter. Large instruments may visually reveal the swirling nature of this striking planetary's inner clouds when viewed through a high-power eyepiece, but it is unlikely that the dim outer cloud will be detected.

4- to 6-inch scopes:

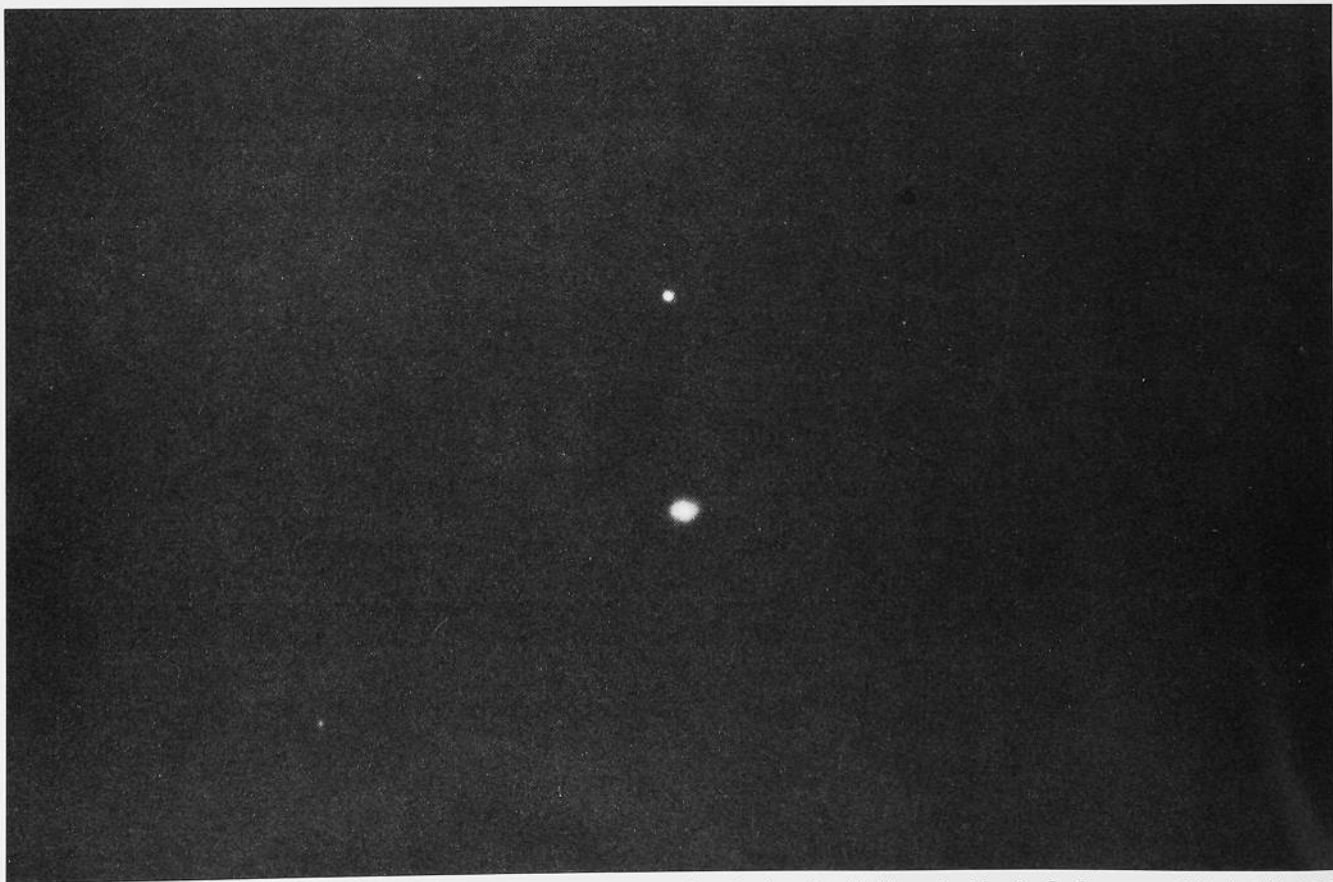
Campbell's Star

Stats: R.A. 19h 34.8m, Dec.

+30° 31' Constellation:

Cygnus Magnitude: 9.6p Size: 8"

A surprisingly bright planetary nebula is located about 2.5° north of Albireo, but few people have ever seen it. The Herschels never saw it, nor does it belong to the NGC. Its posi-



The tiny planetary nebula NGC 6543 in Draco requires high power for viewing detail. Photo by Martin C. Germano (8-inch f/10 SCT, 103a-F film, 30-second exposure).

tion is plotted on *Sky Atlas 2000.0* and the older *Skalnate Pleso Atlas of the Heavens*, but it is unlabeled on both. *Burnham's Celestial Handbook*, the Webb Society's *Deep Sky Observer's Handbooks* and most other modern observing guides let it pass without notice. What is this planetary?

In 1893 the American astronomer William Wallace Campbell was observing through a visual spectroscope at Lick Observatory when he happened upon this strange object in southern Cygnus. From its spectrum it was clearly not an ordinary star, but rather a tiny planetary nebula. Today we know it as Campbell's Star, although it is labeled on *Uranometria 2000.0* as PK 64+5.1, a designation from the *Catalogue of Galactic Planetary Nebulae* by L. Perek and L. Kohoutek.

Measuring only a few arcseconds across and set in one of the richest star fields around, it is easy to understand why so many have mistaken it for a star. Indeed, the German astronomer Friedrich Arge-lander listed it as just that in his famous *Bonner Durchmusterung (BD)* star catalog some

forty years before Campbell's discovery. Through today's modern instruments Campbell's Star is only recognizable as a planetary when viewed with moderately high magnification. At 200x my 8-inch reflector reveals a tiny, 9th-magnitude grayish disk. My notes do not specifically recall a central star, although at 10th magnitude it must certainly be in the range of an 8-inch.

Perhaps with its position labeled on *Uranometria 2000.0*, Campbell's Star will enjoy a popularity among amateurs.

8- to 10-inch scopes:

NGC 6445

Stats: R.A. 17h 49.2m, Dec. -

20°01' Constellation:

Sagittarius Magnitude: 13.2p

Size: >34"

NGC 6445 would be a much more difficult planetary nebula to find if it were not for its brighter neighbor to the south. NGC 6440, a 10th-magnitude globular cluster, forms a picturesque 0.5° wide pair with our target planetary when viewed through a wide-field eyepiece.

Using my 8-inch Newtonian I found NGC 6445 to be a "pretty large, bright planetary; white in color, round with some surface irregularities noted

through 200x." Not even the slightest hint of the central star will be detected through any amateur instrument since it feebly glows at 19th magnitude.

12- to 14-inch scopes:

NGC 6578

Stats: R.A. 18h 16.3m, Dec. -

20°27' Constellation:

Sagittarius Magnitude: 13.1p

Size: 9"

NGC 6578 is one of a pair of planetary nebulae found to the north of Mu Sagittarii. (The other, NGC 6567, proves a worthy challenge through 6- to 8-inch scopes.) It may be easily located just north of 5th-magnitude 16 Sagittarii. Unfortunately, the brilliance of this star all but obliterates the planetary's faint smudge. Your best chance at glimpsing this weak shell of gas occurs on a clear night when the air is calm and steady. Try your highest usable power in order to remove the star from the field of view. Given clean, aligned optics, NGC 6578 will reveal a round, smooth disk highlighted by a 14th-magnitude central star.

16-inch and larger scopes:

PK 36+17.1

Stats: R.A. 17h 53.6m, Dec.

+10°37' Constellation:

Ophiuchus Magnitude: 14.7p

Size: 156"

PK 36+17.1, also known as Abell 43, is an obscure planetary about 5° southeast of Alpha Ophiuchi in northern Ophiuchus. The only published report of its appearance through amateur telescopes appeared in this magazine four years ago. Dana Patchick referred to it as "difficult without a filter" through a 17.5-inch reflector. With a DS 300 filter in place on an eyepiece producing 100x, he saw "an 80 arcsecond diameter bright ring with a central star." In the same issue Jack Marling recalled it as a "pretty easily visible, uniformly round object" through an 18-inch instrument at 80x with an O III filter.

These observations indicate that the large surface area of PK 36+17.1 is best seen with about 100x. Even so equipped I have been unable to duplicate their findings through my 13.1-inch f/4.5 reflector. But I know it can be done! Tokuo Nakamoto spotted it through a 10-inch f/5 reflector but "only because I checked a photo for a position." So it must be out there. I guess I'll just have to try a little harder this year!

54A Dillmont Drive
Smithtown, New York 11787



Large, faint, and irregular, NGC 6445 is a strange sight in large telescopes. Photo by Jack B. Marling (24-inch f/15 Cassegrain, 30-minute exposure).

Turn Left At Orion; A Hundred Night Sky Objects to See in a Scope — and How to See Them by Guy Consolmagno and Dan M. Davis. 200 pp., cloth, \$26.95. Cambridge University Press, New York, 1989. (ISBN 0-521-34090-X.)

The first observing experience is usually a frustrating one for most amateur astronomers. Trying to find faint deep-sky objects seems like a monumental task. Then, knowing what to expect once you found the object can lead to more frustration. These commonplace problems for the novice astronomer are what prompted Consolmagno and Davis to write *Turn Left at Orion*. Because of the first hand experience the authors approach the subject in the simplest manner and one that is sure to minimize, if not alleviate, frustration.

When I first heard about the book, I thought "This sounds like it's going to be a fun book." And I was right. The book begins with a brief introduction to observing. This introduction covers the essentials needed to use the book. The authors describe daily and seasonal motions of the stars that are easy to understand with illustrations that clearly summarize the text. Descriptions of the various types of deep sky objects are accompanied by drawings that give you a good idea of what each looks like visually. The always important, and often misunderstood, image orientation is explained and illustrated correctly. The illustration they use shows normal view (i.e., with the naked eye) inverted, and reversed — important information since each object has one drawing in each orientation.

After the general information, the authors dive right into the observing section. The book is broken down by season, with a sky map that shows the brightest stars in the sky during each season. After that they begin describing objects one at a time. For each object there is a finder chart which shows the region as it appears to the naked eye.

Next, there is a drawing of the region as seen through the

finder scope. The drawing is inverted to match the view of a straight-through finder, the type most commonly included with small telescopes. Finally, there is a telescopic drawing of each object, which is reversed to match view through a refractor or catadioptric with diagonal. All the drawings in this book are a fair representation of what you can expect to see.

In the text, the authors give directions to star hop to each object. The directions assume you are beginning with that object, even if the one of the previous page is right next to the one you are currently looking for. So you don't need to refer back to another page to get the directions for the object for which you are searching. And, for those that would rather use setting circles, a complete list of the objects described in the book is given with epoch 2000.0 coordinates.

For each object, the authors also indicate what type of sky conditions are needed and the best magnification with which to observe (i.e., high power or low power). They also have a rating system to classify each object: four telescopes indicates the most spectacular and easiest to see, while one telescope indicates least spectacular and more difficult to observe. (The only exception is the Orion Nebula which received five telescopes.)

Although *Turn Left at Orion* is an excellent book for small telescope users, it does have a few problems worth mentioning. First, several words and phrases are not defined the first time they are used. For example, the term averted vision is used throughout the book but defined only in the glossary. Spectral classification is used freely but not defined until halfway through the book, and then only in a sidebar.

The directions used in the lunar observing section date from before 1960, prior to the current usage. Although the authors point this out, this can produce confusion as the reader becomes more involved in observing and must relearn the correct directions. It would have been better to explain the cor-

rect orientation to begin with. Furthermore, the authors point out specific lunar features on full disk lunar photos, making it difficult to discern which feature they are referring to. Close-up drawings or photographs would have been nice to show specific features in detail.

As the resurgence in small telescopes continues, this book will be of use to all users of such instruments. Since many of the objects covered in *Turn Left at Orion* can be seen from light-polluted skies, this book is a valuable asset even if you live in a large urban area.

A Manual of Advanced Celestial Photography by Brad Wallis and Robert Provin. 388 pp., cloth, \$39.50. Cambridge University Press, New York, 1988. (ISBN 0-521-25553-8.)

Although published nearly two years ago, this book has failed to achieve the recognition in the amateur community it deserves. This is primarily due to the title, *A Manual Of Advanced Celestial Photography*, which has probably scared more than one potential buyer. Although the book is not for neophytes, it is also not just for advanced astrophotographers either. It is for anyone who wants to be an advanced astrophotographer. This extensive volume compares to a small encyclopedia on celestial photography and would have been more aptly titled *A Complete Manual of Celestial Photography*.

The authors, Brad Wallis and Robert Provin, have produced a work that will become the standard by which all other books on astrophotography are measured. The authors discuss, in detail, topics that are never mentioned or given only a cursory treatment in other astrophotography books.

Furthermore, the information Wallis and Provin present comes from years of firsthand experience, both at the telescope and in the darkroom.

A great deal of the book is devoted to theory. In fact, it is not until the later chapters that the actual processes and tech-

niques of astrophotography are mentioned. Of the two chapters on application, one focuses on deep sky photography while the other is on high resolution photography (i.e., planetary work).

The book begins with a history of astronomical photography. Although the chapter is titled "A brief history of astronomical photography" it is the most extensive treatment I have seen in a single volume.

Next the authors jump into instrumentation, beginning with optics. Detailed attention is given to numerous optical systems including both commercially-produced and handmade. The design of each optical system is discussed briefly with a summary of its strengths and weaknesses. The authors have their biases which they don't hide, but some produce contradictions. For example, the authors state the main drawback to Schmidt cameras are their fast focal ratios, citing a f/1.7 system as an example. Yet two paragraphs earlier they extoll the virtues of an f/1.5 Maksutov camera.

After optics, the authors discuss telescope mounts. The concrete advice Wallis and Provin offer is extremely beneficial, especially if you haven't already invested a fortune in a mount.

Next, the authors discuss photographic theory in detail found only in books devoted exclusively to photographic science (most of which are out of print). These chapters alone are worth the price of the book. Wallis and Provin also discuss which films are best for astrophotography and why. Even the seasoned astrophotographer will find a few surprises here.

The authors then spend two chapters on darkroom techniques, one on introductory techniques, the other more advanced. This is one area where the author's experience shows. Photographs demonstrate before and after results and illustrations show how to perform the procedure.

The chapter on hypersensitizing techniques covers all the methods available to the amateur. Seldom used techniques,

such as pre-flashing, are given lengthy explanations. Not only do the authors discuss how to do it, but they give simple plans on how to build a pre-flashing device.

The end of the book contains a gallery of celestial photographs taken by the best in the business. Featured are Coombs, Rouse, McClure, Potter, Germano, Dragesco, and yes, Wallis and Provin.

The last chapter, which reads more like an appendix, is a compilation of articles by respected experts in the field. Jim Rouse discusses planetary photography, Jack Marling talks about filters, Ron Potter about auto guiders, and Jack Newton about cooled emulsion photography.

Initially, I found two major drawbacks to *A Manual of Advanced Celestial Photography*. The first is the number of illustrations. Although all are of excellent quality, the quantity seemed rather sparse for a book of this size.

Second, I was a bit put off by the somewhat arrogant attitude of the authors. Other amateurs have expressed the same feeling, a factor which may have also affected the acceptance of this book. However, as I looked through other books, most of which condone a halfhearted approach to the subject, it became clear what the authors are simply trying to say: "If you're going to do astrophotography, do it right!" Wallis and Provin have done just that. Their work speaks for itself.

Observing Variable Stars; A Guide for the Beginner by David H. Levy. 190 pp., cloth, \$19.95. Cambridge University Press, New York, 1989. (ISBN 0-521-32113-1.)

Most books aimed at the beginning amateur astronomer are general in scope, usually covering a wide range of topics to touch on something that will interest every reader. Conversely, observing books that are very narrow in scope are usually for more advanced observers.

But David Levy's book on variable stars is a welcome departure to this norm. Here is an entire book directed at the beginner that deals essentially with a single subject — variable stars. But don't think this is just for newcomers to amateur astronomy. This book is also for experienced observers who may be trying their hand at variable star observing for the first time.

The author, an active variable star observer, shares his experience with a contagious enthusiasm that is informative and entertaining.

Observing Variable Stars is broken down into four sections. The first, a general introduction to the night sky, covers the usual topics in an often times unusual manner. In addition to pointing out the constellations, Levy also suggests making up your own. At first I thought this might be confusing. But the project is fun and will get you outside looking at the stars instead of studying star maps, an often times confusing task for the newcomer.

In these introductory sections basic concepts about magnitude and star color are discussed briefly. Equipment needed for variable star observing is also considered. Binoculars and telescopes are discussed with practical tips on how to buy the right instrument.

The next section, the one I found most interesting, is the *dis* stars themselves. Levy describes the different types of variables, how to find them, and how to observe them once you find them. He includes interesting anecdotes that will stimulate your interest and curiosity. The book contains numerous charts to help make sense of the star hopping directions described in the text. But be aware that the charts contain several errors. If you have difficulty finding an object, or if the direction in the text doesn't match the chart, consult another source.

The third section is a seasonal guide to variable stars. Within each season, the author breaks down variables by constellations for easy reference. Each entry includes the variable star designation, magnitude range, and interesting tidbits about the star. Levy also rates each entry from level 1 (easiest) to level 5 (most difficult) so you know if the star is within the grasp of your observing skills. Like the previous section, this one includes several charts to help you locate selected variables.

Levy's book concludes with a miscellany that describes the pioneering work of early variable star observers along with a description of the AAVSO's work. The author lists plenty of other books for the reader who wants to get more involved in variable star observing.

Something that really impressed me was that the author is aware that there are observers in the southern hemi-

sphere who will read his book. From the first section to the last, Levy mentions southern constellations and variable stars.

If you think variable star observing is boring, this book will convince you otherwise. Most importantly, *Observing Variable Stars* will get you outside looking at the sky.

Observing The Constellations; an A-Z Guide for the Amateur Astronomer — Fully Illustrated with Star Maps and Photographs by John Sanford. 200 pp., paper, \$16.95. Simon and Schuster, New York, 1989. (ISBN 0-671-68924-X.)

Finally, we have a concise observing guide that covers all 88 constellations. Before *Observing The Constellations* the only other guide that covered the entire sky was *Burnham's Celestial Handbook*. This three-volume monster was designed for reference use, not as a field guide to accompany the observer to the telescope.

Although not as detailed as *Burnham's, Observing The Constellations* contains a wealth of information. And even though it is technically an observing guide, this book is also useful as a reference. The author, John Sanford, is an experienced observer whose years of experience show throughout the text.

Observing The Constellations begins with a short introduction that is much too short. More general observing tips would have been helpful, especially for novice observers.

Following the introduction is a discussion of each of the constellations, listed alphabetically for easy reference. Some of the smaller, less populated constellations are lumped together with neighboring constellations.

Included in each section is a brief explanation of the constellation's origin, a feature that adds to the book's usefulness as a reference. From there, the author jumps right into the text, guiding the reader through each constellation, pointing out objects of interest. And unlike many books which emphasize deep-sky objects to the exclusion of everything else, this one includes many double and variable stars.

Reading descriptive text can often times be difficult and boring. But Sanford's style is easy-to-read, flows well, and reflects his experience as an observer.

The objects described in the text are summarized by a chart

which gives coordinates in 2000.0 epoch. This makes for easy reference when trying to find an object, particularly if you use setting circles.

Aside from the main text there are several sidebars which are designed to further enhance the reader's knowledge of astronomy. The only problem is some side bars near the end of the book contain information needed to understand earlier portions of the text. For example, the text refers to the spectral classifications of stars, but the side bar that contains the explanation is halfway through the book. This information belongs closer to the front of the book, perhaps in the introductory section. Other terms, like HII regions are defined only in the glossary, while still others, like the Sb galaxy classification, are never defined.

Each constellation is illustrated with a sky map drawn by the well-known astrocartographer, Wil Tirion. The sky maps show stars down to 6th magnitude and include some of the deep-sky objects described in the text. In addition to the sky map, there is also a wide-angle photo of the same region.

Personally, I prefer photographs over maps since they generally give a better idea of what to expect visually. However, these photos suffer from varying image density, inconsistent image scale, and inconsistent orientation which makes them difficult to use, both in conjunction with the sky map and each other.

In addition to the constellation photos are others that show close-ups of many objects described in the text. They range from amateur photos by such greats as Ronald Royer to those taken by professional astronomers using state-of-the-art equipment. Amateur observing guides should use photos taken with amateur equipment to give the reader a fair idea of what he or she can do. I don't see the point in showing an image-processed CCD picture of NGC 1598 when the author states in the caption that it is too faint for amateur telescopes.

Overall, this book is well done. The drawbacks are relatively minor and do not seriously affect the book's usefulness. It is a welcome addition to the library of any amateur, both novice and seasoned.

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Small Scope Showcase

Observing with the Herschels

by Alister Ling

It's surprising how little amateurs know about William Herschel, his telescopes, and his observations. Although Charles Messier is usually most closely associated with deep-sky observing, he was mainly interested in comets. On the other hand, Herschel is the acknowledged father of deep-sky observing, since he set out with great purpose to scan the skies for nebulae and clusters.

Two hundred and four years ago Herschel published his *Catalogue of One Thousand New Nebulae and Clusters of Stars*, which he completed in under four years. His telescope was an altazimuth with a speculum mirror just under 19 inches across. It measured twenty feet in length. The mirror was tilted off-axis, to bring the focus to the side of the tube, letting him sidestep the light loss due to a second speculum reflection. This is now known as the Herschelian telescope. His sweeping power, that is the lowest one, was 157, yielding a field of view 15' across. Today an amateur equipped with a 6- or 8-inch scope will have no trouble following in Herschel's footsteps.

Of great interest to William Herschel were "stars with burrs, milky chevelure, short rays, and remarkable shapes." To Herschel and the astronomers who followed him, namely his son John and Lord Rosse in Ireland, these nebulae were perhaps solar systems in the making. Some turned out to be the bright stellar cores of galaxies, but the finest example of this class are the planetary nebulae.

In mid-July of 1784 Herschel came across what we now know as NGC 6894, some 10° south of Gamma Cygni. His description reads: "pretty faint, exactly round, of equal light. The edges pretty well defined, 1' diameter." Forty years later John Herschel (using the same telescope, I believe) called it "extremely faint. Strongly suspected to be annular, but the darkness in the center is not striking." In a later observation he added "the northern limb is the brightest."

Today a 6-inch scope is the minimum size required to spot

this pale nebula. Even owners of 10-inch scopes call the planetary "ghostly." The central darkening can be barely seen with attention. Don't give up too quickly if you can't find NGC 6894 at low power. Try using medium powers, say around 150x. This makes the sky background darker and brings the nebula up in apparent size so the eye can see it. Herschel may never have discovered as many objects if his sweeping power was lower. Small galaxies and especially planetary nebulae can

be indistinguishable from stars at 50 power.

It takes a 12-inch scope to notice the brightening of the northern limb, which is quite a testament to the observing skill and dark skies of the Herschels. Let me know if you can see the brightening with a smaller scope; I believe it should be feasible. Try one of the narrow band nebula filters. Does it help?

A few days later Herschel discovered NGC 6772, another planetary nebula very similar to

NGC 6894, in Aquila. This time he called it "very faint", fainter than the first, and placed "in the midst of the numberless stars of the Milky Way." Can you see it without a filter in an 8-inch scope?

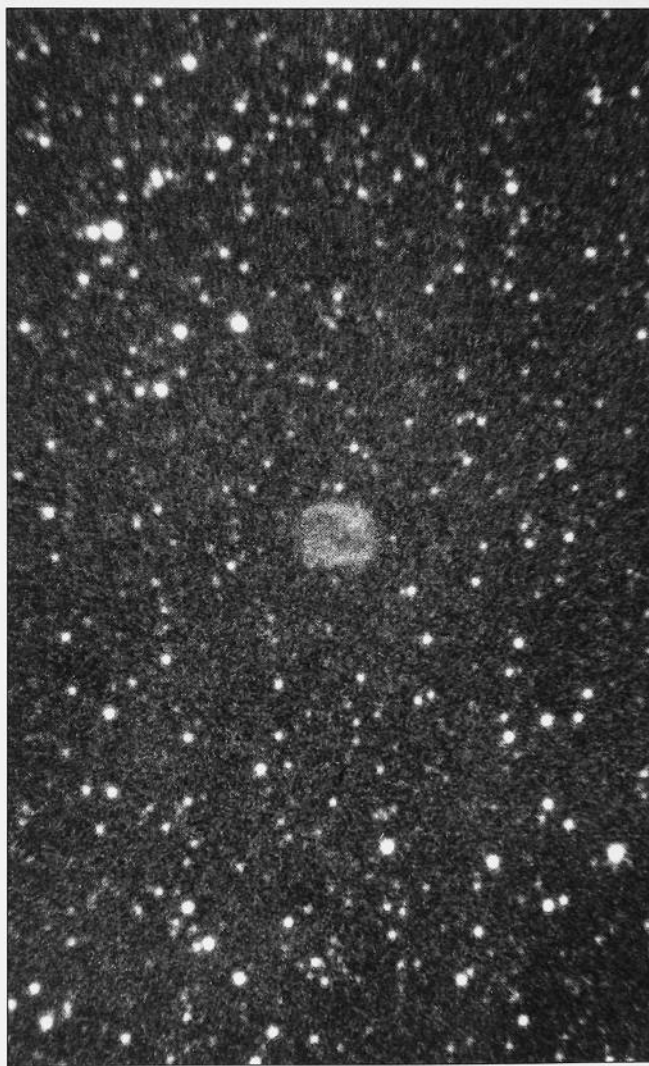
In his quest to understand the structure of the universe, Herschel made observations of dozens of open and globular clusters. Remember that in his day galaxies were thought to be very distant clusters, resolvable in bigger and better telescopes. After all, he had resolved many globulars that were thought to contain no stars at all.

A number of scattered groups of stars were noted by Herschel as "a forming cluster, or one that seems to be gathering." He evidently thought that over time these objects would contract under the pull of gravity to become a more condensed cluster. They were placed in his eighth class: "coarsely scattered clusters of stars".

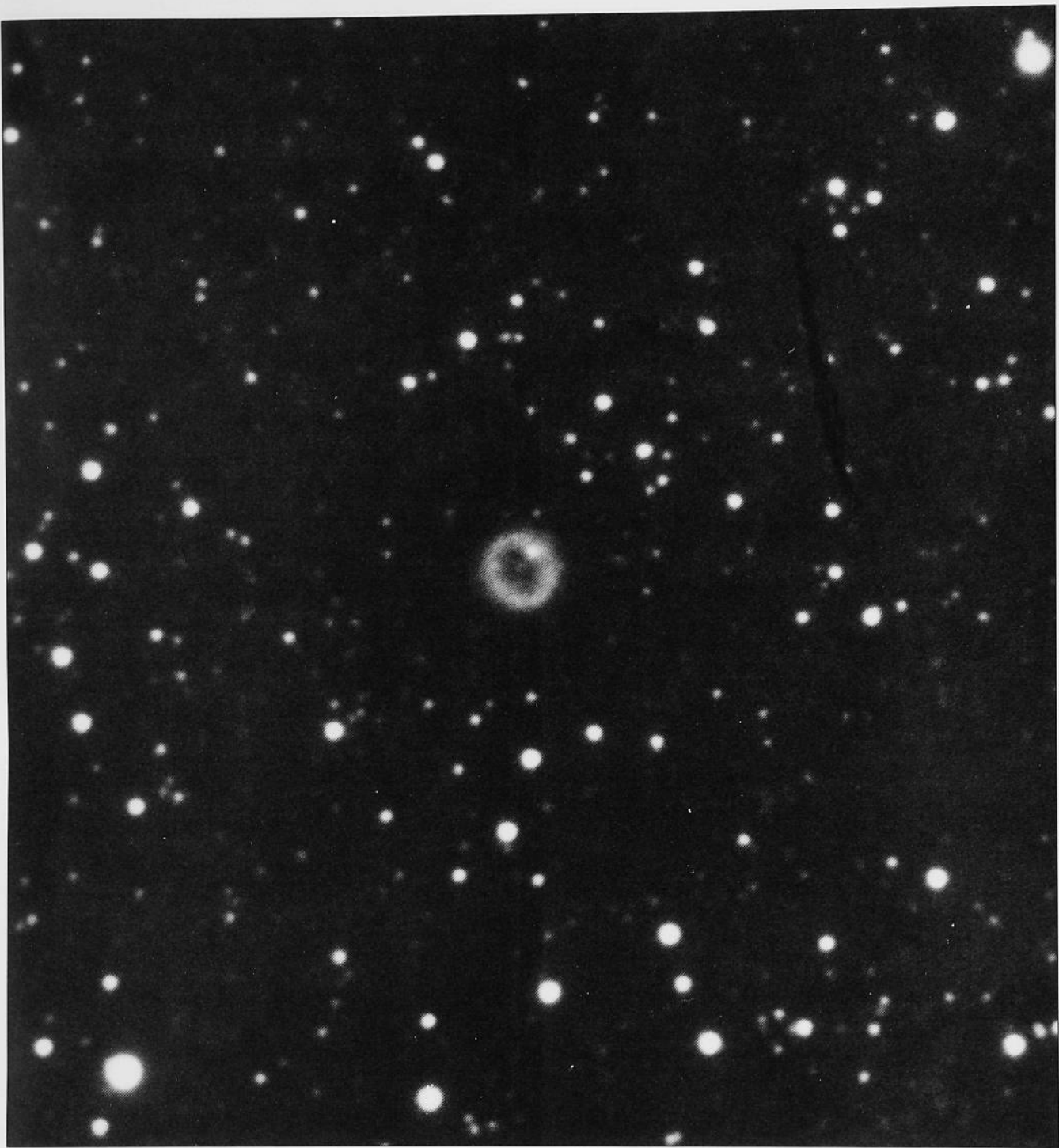
In 1975 Jack Sulentic and William Tifft, in their *Revised New General Catalogue*, reclassified many of Herschel's class 7 objects as "non-existent" on the *Palomar Observatory Sky Survey (POSS)*. This meant that they were swamped in nebulousity or faint field stars and thus unrecognizable. At the eyepiece of an amateur scope, however, any of these asterisms can be readily found. As with Herschel, you will not be bothered by hundreds of 16th- to 20th-magnitude stars.

Among my first rediscoveries of these so-called non-existent objects were NGC 6837, NGC 6840, and NGC 6843 in northern Aquila, 3° north of Altair. Their epoch 2000.0 coordinates are 19h53.3m +11°42' (NGC 6837), 19h55.2m +12°07' (NGC 6840), and 19h56.0m +12°10' (NGC 6843). The first, NGC 6837, is one of two classic types of class 7 clusters. It is a small clump of six stars only 2' or 3' across. At low power this tiny asterism is an undefined smudge that could pass for a galaxy. A magnification of 200x easily reveals its true nature as a small circlet of stars.

NGC 6840 follows the sec-



The peculiar planetary nebula NGC 6772 was discovered by William Herschel in 1784. It is one of the oddest planetaries in Aquila, and has a low surface brightness. Photo by Martin C. Germano (8-inch f/10 SCT, 103a-F film, 60-minute exposure).



A beautiful ring of smoky light, NGC 6894 in Cygnus was also discovered by Herschel in 1784. The low surface brightness of this object makes it a challenging target for small telescopes. Photo by Martin C. Germano (8-inch f/10 SCT, hypered Tech Pan film, 60-minute exposure).

ond type of class 7 cluster, being a round, loose group of two dozen stars, 10' across, that stands out from the background only slightly. Its brightest stars are about 11th magnitude. You may find that 100x brings out the object nicely. Off to the southeast about a half degree lies a beautiful orange 9th magnitude star. Due north of that star, and due east of NGC 6840, lies the last class 7 cluster in

this region, **NGC 6843**. This one was discovered by John Herschel. Basically this is a crooked line of six stars, some 5' long. The younger Herschel described this one as small and poor.

What is fascinating about these asterisms is that they may be physically bound groups, rather than line-of-sight clumps. It takes at least three-color photometry to make conclusions

about their nature. Once color-magnitude diagrams are constructed, one looks for a common family age in the main sequence. Unfortunately, tight funding for professionals leaves precious little motivation for this sort of research. Perhaps some advanced amateurs can do the field some justice by the turn of the century.

As we all know, the state of professional research never

stops amateurs from enjoying the sights and pondering about the universe. If you would like a list of class 7 clusters, drop me a note. There are plenty more asterisms in the sky waiting to be rediscovered.

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Double Stars

Sagitta and Vulpecula

by Brian Skiff

One of the pleasures of casual sweeping in the Milky Way is coming upon a bright, close pair among the endlessly numerous faint field stars. Such a pair often appears to be suspended unnaturally above the layer of background stars; the rarity of two 7th-magnitude stars only a few arcseconds apart is dazzling.

One of the best regions in the northern Milky Way for such sweeping consists of the constellations Sagitta and Vulpecula. Their boundaries straddle the galactic plane, and so they both offer almost endlessly starry fields. Sagitta and Vulpecula contain a number of challenging pairs for any telescope, and these can add a lot of variety to observing lists packed with clusters and nebulae normally viewed in these constellations.

Sagitta

ADS 12160. This pair of stars is currently separated by only 0.7", so an 8-inch telescope is necessary to resolve it. In 1986, using the Lowell 24-inch Clark refractor stopped down to 11 inches, I resolved this pair without difficulty. The stars glow at about magnitudes 7 and 8 and are aligned in position angle (p.a.) 140°. Two distant stars lie in the field, but both are optical companions as evidenced by the large proper motion of the brighter pair.

ADS 12336. I viewed this pair at Kitt Peak in 1988 using my 6-inch refractor. At about 9" separation, the two stars were an easy target even at 50x. I estimated the position angle to be 280° and the magnitude difference (Δm) to be 2.0. The *WDS* lists magnitudes 7.0 and 8.7, a separation of 8.8", and p.a. 284° for 1968. In the field about half a degree south and slightly east is a much fainter uncatalogued pair I also recognized at 50x. They glow dimly at magnitudes 10 and 10.5, and are separated by 15" in p.a. 320°.

Zeta Sagittae (ADS 12973).

Zeta's primary has an extremely close companion and also an easy, distant third component about 8" northwest. Last autumn I found this star easily at 80x in my 6-inch scope. It is an excellent example of a very unequal pair: The companion is nearly four magnitudes fainter than the primary.

Theta Sagittae (ADS 13442, NGC 6873). Yes, an NGC object! The wide, unequal pair (magnitudes 6.4 and 8.9; 12.0" separation) dominates a loose group of twenty fainter stars in a 12' area. Although it is a "nonexistent" *RNGC* object, the cluster is a observable, if weak, visual cluster. It probably is not a real open cluster, and even if it were, the double star is unrelated and very much in the foreground.

J 3028. During a 1989 observation of the globular cluster M71 (NGC 6838) I noticed that two of the brightest resolved stars near the center of the cluster formed a relatively conspicuous pair at high power in the 6-inch scope. Such faint, wide pairs were often catalogued in this particular declination zone during work done about the turn of the century on the *Astrographic Catalogue*.

Later, I scanned through the *WDS* and indeed found a pair matching my estimates at the coordinates of the cluster. But instead of the name of one of the *AC* cataloguers, the star had first been noted by the French amateur double star observer Jonckheere, who also had a penchant for faint, wide pairs in the Milky Way. His original 1944 observation included only estimates of magnitudes 13.0 and 14.0, with a separation of 3" in p.a. 305°.

Since then, of course, the cluster has been well observed by professionals. The two stars turn out to be among the brightest members of the cluster near the tip of the giant branch; the brighter star may be the bright-

est cluster member.

Using data from an astrometric study of the cluster, I find the separation to be 4.2" in p.a. 315°. Even though both are likely members, they are not a binary in the usual sense. The magnitudes are somewhat brighter than Jonckheere's estimates, but are uncertain. Two sources give the following V magnitudes and B-V colors:

Cudworth:

12.12 / 1.88 12.79 / 1.25

Sandage:

12.08 / 1.84 12.53 / 1.45

Because they are luminous red stars, both are likely to be variable to some degree, like the M-giant semiregular variable stars in the general field. The small differences in the values for the brighter star are thus negligible and are likely due equally to variability and uncertainty in the actual measures. (Since the stars are crowded, the measures may be contaminated by light from other stars.)

The difference in the magnitudes for the fainter stars in the two sources is perhaps permissible, but the color difference is not. The measures by Sandage were done photoelectrically with the Palomar 5-meter telescope, so one might prefer them. Cudworth's photographic measures were carefully calibrated (and done more recently), however, so it is not easy to dismiss them. It is possible both measures are affected by crowding, or one is closer to the truth than the other. But without further observations, it is not possible to decide.

Vulpecula

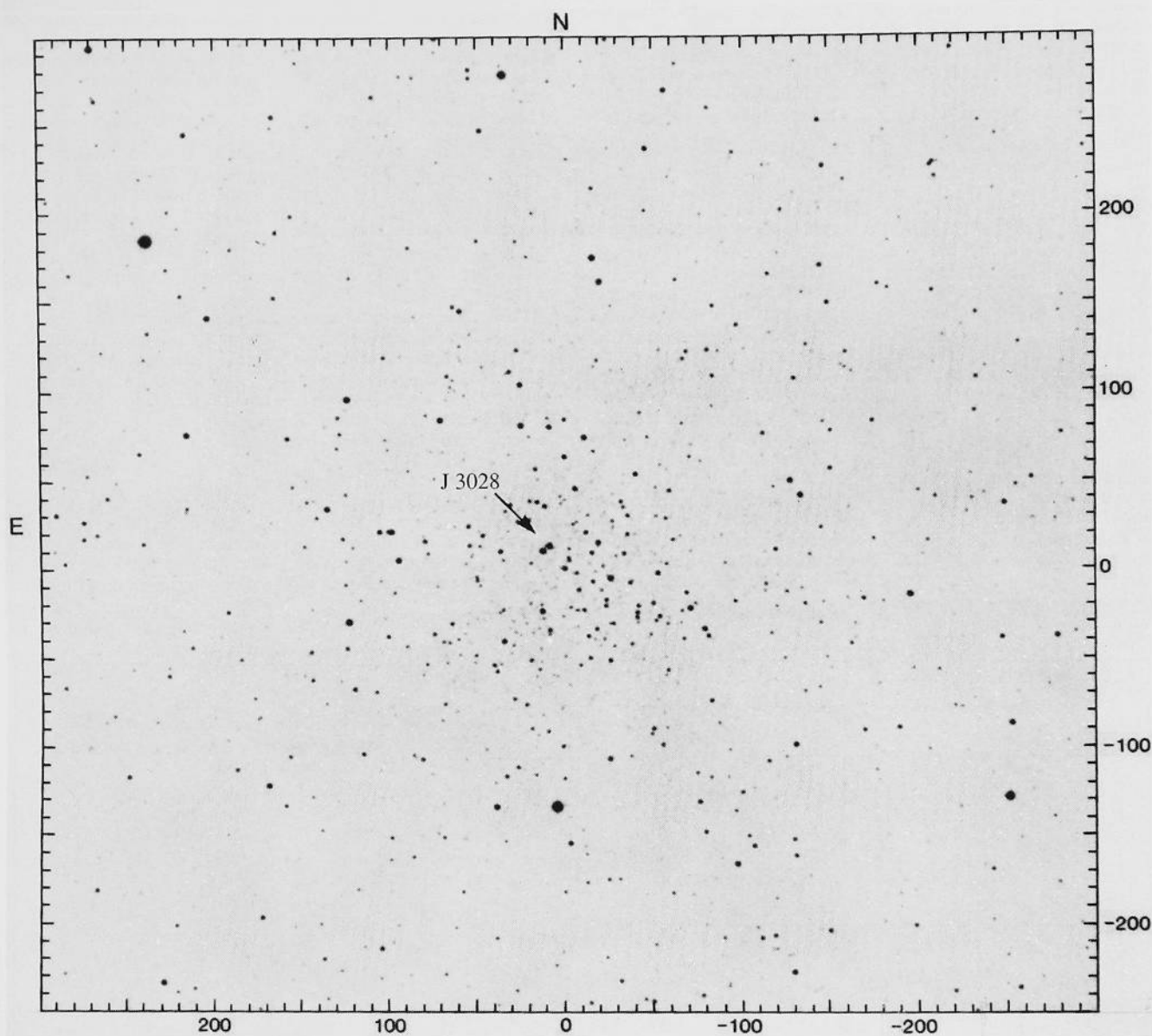
ADS 12594. This is the first fairly bright star east of the faint open cluster NGC 6802. I resolved it at just 50x in the 6-inch. At 165x I estimated Δm of 1.2 and p.a. 145°. Published photometry for the pair implies V magnitudes of 7.5 and 9.0. The *WDS* lists p.a. 149° for 1973.

ADS 13050. This is an easy, matched pair for medium powers with a third, fainter component. At 165x I saw a slight difference between the stars, which are 3.9" apart in p.a. 135° (my estimate; the *WDS* lists p.a. 139°). The third star is nearly in line with these and is 31" away. I estimated it to be 1.2 magnitudes fainter than either components of the close pair.

13 Vulpeculae. I credit Paul Brown for making me aware of this difficult pair. In my regular survey of bright pairs I probably would have skipped it. The best current values for the stars are: V magnitudes 4.6 and 7.6 and a separation of 1.1" in p.a. 243° (1981). From Canada in 1987 Paul managed to detect the faint secondary in his 8-inch Newtonian at very high power, and suggested I try it with the Lowell Clark. Stopped to 8 inches, I was able to duplicate Paul's observation at 405x. I could see nothing definite with the telescope stopped to 6 inches, but when it was opened up to 10 inches the companion was well shown as seeing permitted.

16 Vulpeculae (ADS 13277). This star is a challenge object for a 6-inch telescope. A 1985 speckle interferometry measure placed them just 0.85" apart in p.a. 121°. In 1987 using the Lowell Clark stopped to 6 inches, I saw two Airy disks overlapped by perhaps 20 percent at 405x. By opening up to 8 inches, the disks shrunk and were then just separated.

Last autumn I got essentially the same result with my 6-inch refractor, and the disks appeared to overlap slightly at 410x. During that observation, I estimated a Δm of 0.6, whereas with the Clark I'd estimated 0.5. The *WDS* value is 0.4, so both visual estimates were close. In November 1989 I used this star on several nights to guide photos of Comet Skorichenko-George with the 13-inch "Pluto Camera." In its 7-inch guider



This photograph made with the Yerkes 41-inch reflector by Kyle M. Cudworth shows the prominent double star J 3028 in the central part of globular cluster M71. From Cudworth, *AJ*, **90**:65 (1985).

the pair was just resolved even though it (and the comet) were quite low in the sky. It's always on nights with terrific seeing like this that I have to work!

ADS 14424. This is a fainter, closer pair that requires a 10-inch scope for a clear view. The two stars glow at about magnitude 8.5 and are just 0.5" apart. Using the Clark at 10 inches, I saw them oval and occasionally

resolved at 405x.

h 1557. This obscure pair (equinox 2000 coordinates: 20h 39.3m, +27°15') was on my observing list of *galaxies* in Vulpecula! It was catalogued in modern times first by Fritz Zwicky as a "pair of exceedingly compact blue spherical galaxies." Peter Nilson followed suit in the *UGC* catalogue, where they're designated UGC

11608 and UGC 11609. Both authors, to be fair, left open the possibility that they were stars, just as John Herschel had catalogued them over 150 years ago.

Visual inspection shows h 1557 is just a pair of magnitude 10.5 stars out in the relatively star-poor eastern reaches of the constellation. There are galaxies not far from here, but not here.

An easy target in the 6-inch, the *WDS* specs for the pair are magnitudes 9.5 and 9.8, 13.4" separation in p.a. 209°. Neither star is in the *BD* catalogue or the more recent *AGK3* astrometric catalogue, so I suspect my magnitude estimates of 10.5 and 10.8 are closer to the actual values.

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Variable Stars

Books Past and Present

by David H. Levy

When I started observing in 1966, there were few books in existence that were devoted entirely to variable stars. Our bible back then was Margaret Mayall's *Manual for Observing Variable Stars*, a thin volume rich with instructions for observing the different types of variables. A version of this booklet is still the standard introduction for variable star observers. Its roughly forty pages describe how variables are named and a bit of their history, as well as simple and important observing aids like how to orient charts, how to make an observation, and how to report your work. Although this important book is not available in book shops, it is included in every new member's package when they join

the American Association of Variable Star Observers.

One of the earliest variable star books was Leon Campbell and Luigi Jacchia's *The Story of Variable Stars* (Blakiston, 1941.) Part of the famous Harvard Books on Astronomy series, this book had a major role in expanding the AAVSO's membership and influence during the postwar period. "The observations themselves are not difficult," the authors claimed. "No expert astronomical or mathematical knowledge is required and the results attained attest to the great value of the work. In fact, this sort of observing is admirably suited to the amateur and is the one field in which success as an observer can be attained with a fair amount of perseverance." The

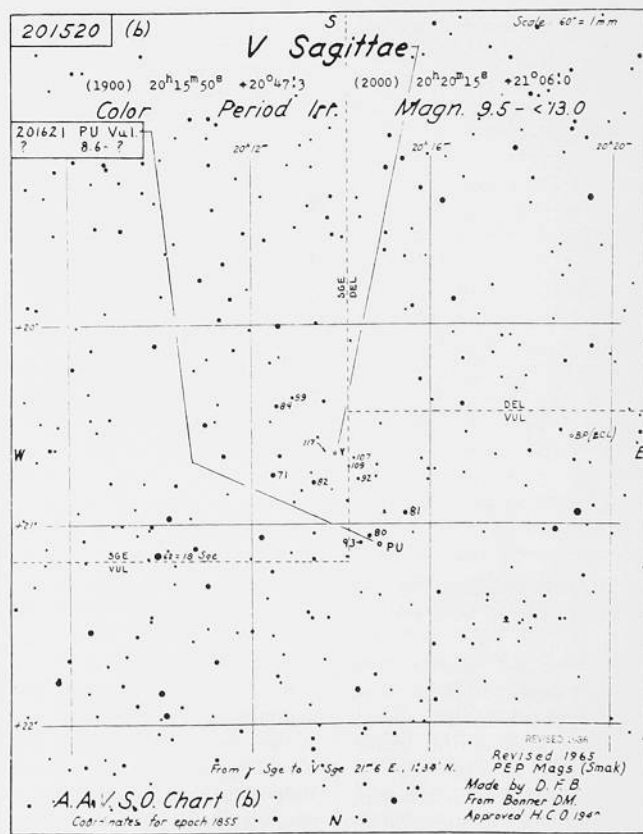
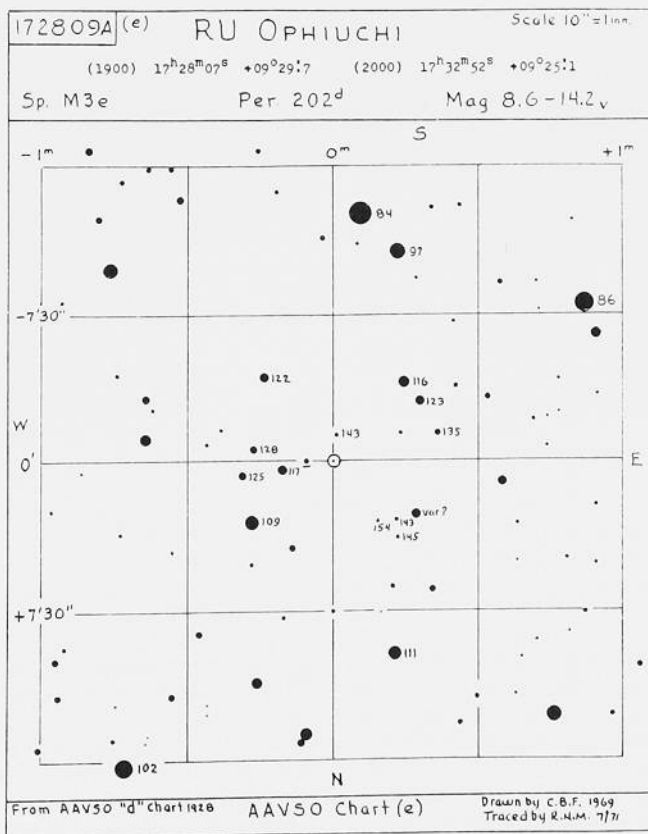
book ends with a call to action: "Let us refute the Emersonian declaration that the man in the street does not know a star in the sky."

In 1955 Campbell produced his *Studies of Long Period Variables*. Published by the AAVSO and, unfortunately, long out of print, this 247-page study of four hundred Mira-type variables helped to gain respectability for the AAVSO's variable star archive. J. S. Glasby's *Variable Stars* (Constable, 1968) provided a 1960s introduction to the study of variables. Although it contained little information on how to observe these stars, it did provide an overview of the many types of variation that one can expect to find.

Four years later W. Stro-

meir's *Variable Stars* (Pergamon, 1972) appeared as a scientific introduction to variables designed for graduate-level astronomy students. Those of us hoping to see our visual work reduced to scientific knowledge found it "reduced" in a different way. Compare this author's comment on page 5 with that from Campbell and Jacchia: "Visual estimates, however, are not sufficient for precise and accurate descriptions of light variations, since the human eye has too many physiological problems."

While this is certainly true for hundredth of a magnitude differences, it is not true for the Mira stars, which have leisurely months-long periods with multi-magnitude changes that can conveniently be followed by



A telescopic finder chart for RU Ophiuchi shows the field immediately surrounding the variable. All charts courtesy Janet A. Mattei, AAVSO.

The unpredictable variable star V Sagittae lies in a particularly rich star field, as depicted in this telescopic finder chart.

amateur astronomers with appropriate accuracy. Moreover, the sudden three- to six-magnitude outbursts of cataclysmic variables are easy to spot by visual observing, and astronomers often wish to be alerted to these events. Despite this comment, Strohmeier's book is an important study of our understanding of variable stars in the early 1970s.

In 1985 Storm Dunlop translated *Variable Stars* by C. Hoffmeister, G. Richter, and W. Wenzel (Springer-Verlag, Inc., 1985), producing, in my opinion, the best variable star read in recent times. Although this book does not consider observing techniques, it is a mine of information about all types of variable stars and a must for anyone seriously interested in the science behind their observations. So helpful has this book been to me that one time when I wanted to learn something about comets I instinctively turned to it before realizing that I was way off the subject.

The most recent book on variable stars emphasizes not the

stars themselves but how to observe them. In my *Observing Variable Stars: A Guide for the Beginner* (Cambridge University Press, 1989), I take the reader through a series of steps designed to ease entry into the world of observing these stars.

This list is intended only as a sampling of books on variable stars that have appeared over the years. Each has its own unique perspective. Were all the authors to get together, I'm sure

they would disagree avidly on substance and approach. One thing they would not disagree on, however, is that the field of variables is big enough to absorb all these points of view.

Here are some recommended stars for summer observing:

172809 RU Ophiuchi. This Mira star has a 4.5-magnitude range from 9.1 to 13.6 over a period of 202 days. Although it is faint, RU Ophiuchi is easy to find by moving your telescope

about 30' west and slightly south from the 5.8-magnitude star 53 Ophiuchi.

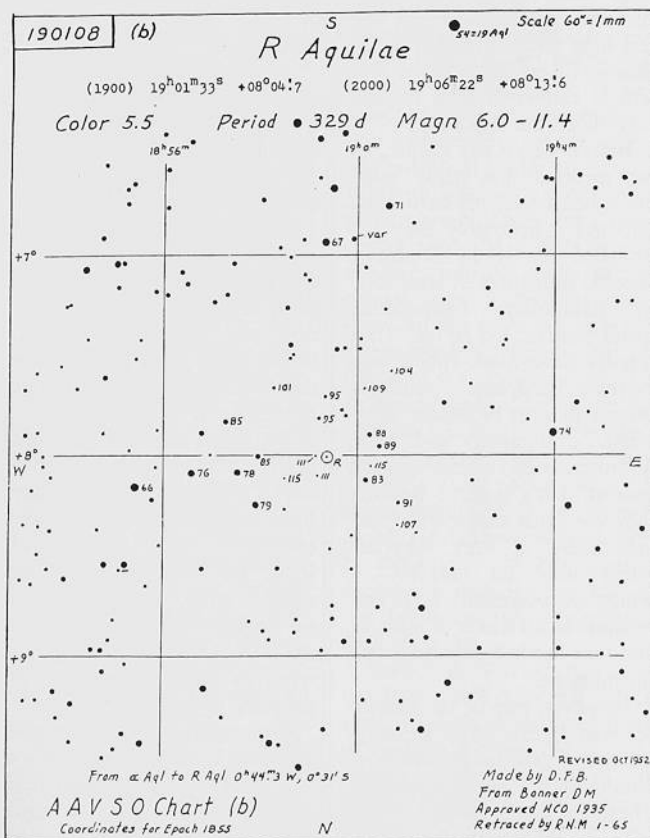
183308 X Ophiuchi. One of the shallowest Miras known, this bright star has but a two-magnitude range, typically from 6.8 to 8.8. Its period is 335 days. Because the range is so small, it is not necessary to observe this star more often than once a month.

190108 R Aquilae. Only 30 minutes east of X Ophiuchi is R Aquilae, the first star to be discovered to vary in Aquila. The star's 6.0 magnitude maximum makes it plainly a binocular object, although the star fades to 11.4 at minimum. At 329 days, its period is almost identical to that of X Ophiuchi.

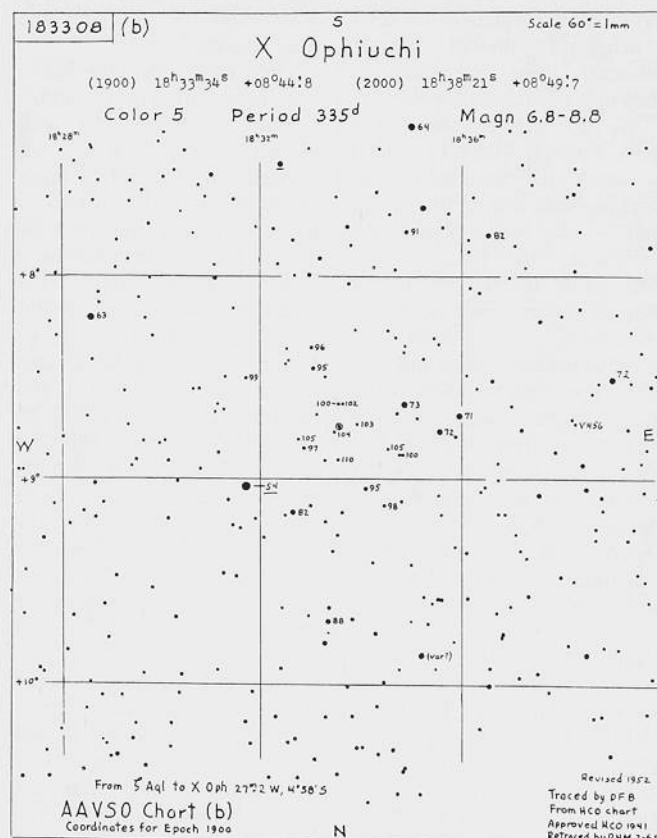
201520 V Sagittae. This unpredictable variable changes slightly from night to night is likely an old nova. Its range is currently 8.6 to 13.9. It is also an eclipsing binary with a range of 0.6 magnitude. This difficult star is north and west of the 6th-magnitude star 18 Sagittae.

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Although Variable Stars by Hoffmeister, Richter, and Wenzel does not consider observing techniques, it is a mine of information about all types of variable stars and a must for anyone seriously interested in the science behind their observations.



Aquila's first variable star is R Aquilae, a Mira-type star shown in this binocular finder chart.



X Ophiuchi is a Mira star with one of the shallowest range of variations known. This is a binocular finder chart.

Scanning the Literature

Galaxies and Their Magnitudes

by Brian Skiff

In the Winter 1989-90 issue Ernie Ostuno described a collection of galaxies generally close to the galactic plane. Readers have told me they were impressed (or even a little incredulous) at how faint Ostuno could see with his 10-inch telescope from Connecticut, saying they've tried for 15th-magnitude galaxies before with much larger apertures without luck. What gives?

The answer simply is that those galaxies aren't really 15th-magnitude objects. To explain why will take much doing, and for the next few issues this column will deal with this problem. It is something I find myself explaining over and over in conversations with friends and correspondents. Several fundamental misconceptions prevail among amateurs about magnitudes as they apply to nonstellar objects.

To give you an example, I went through Ostuno's article — which apart from the magnitude problem was an interesting one — and found photometry for objects where he cites a specific value for the brightness. Not all objects have published photometry on standard systems, so the list is short and possibly not representative. (The many bright objects had no magnitudes given with the article and are omitted from the list below.) The four columns give the object name, the magnitude Ostuno cites, the total B (blue) magnitude, and the total V (yellow or visual) magnitude.

Name	Ostuno	B(T)	V(T)
N1167	14.0	13.4	12.3
N2342	12th	—	12.6:
IC456	15.0	13.0	11.9
E/G14	15th	13.3	12.2
E/G11	—	13.3	12.2
N2525	12.3	12.2	11.5
N2566	13th	11.8	11.0
IC2311	14th	12.5	11.6

The magnitudes cited in the article for these objects are as

much as three magnitudes off from those determined on well-defined systems; the faintest object in the sample is only about magnitude 12.5. Having viewed several other of those "15th magnitude" stinkers in the article in my 6-inch telescope, I'd be willing to wager that the faintest objects mentioned have total V magnitudes around 14.0.

Incidentally, I added ESO 428-G11 to the list because it is in the same medium power field with G14 and is just as bright. Ostuno omitted it presumably because it is not plotted on *Uranometria*.

It is difficult to know where to start. As we progress, I'll be glad to backtrack as necessary when unexplained topics come up. This will depend a lot on your responses, so let me hear your reactions.

Let's start with some basics, like how different magnitude systems are defined. The well-known UBV system was devised by Harold Johnson about 1950. Its purpose was to try to determine spectral types of faint stars without having to actually take a spectrum. At that time it was difficult and prohibitively time-consuming to get spectral classifications of stars fainter than about 9th or 10th magnitude, and that's still the case. (This column is supposed to provide a gateway into the technical literature: the original paper describing the UBV system and its relation to MK spectral classifications was published in 1953 in the *Astrophysical Journal*, volume 117, page 313.)

Improved spectrographs and detectors have made going faster easier, but hardly anyone attempts to get spectra of faint stars at high-enough resolution to classify them on the MK system, which is the standard one used for classifying stars in a general way.

The UBV system uses three filters to isolate three color bands in the visible part of the

spectrum. They are centered at about 5500Å in the yellow (or visual, leading to "V"), 4400Å in the blue (B), and at 3650Å in the near ultraviolet (U). The bandpasses are each about 1000Å wide, and overlap to a considerable degree. Taking his cue from the old photographic system then in use, Johnson arbitrarily set the color of a star of type A0V, such as Vega or Sirius, at zero. The colors are formed by taking differences of magnitudes in any two filters, viz. B-V ("B minus V") or U-B ("U minus B"). Vega itself had been used for many decades as a zero-magnitude star. In the UBV system, Vega has a V magnitude of zero, and B and U magnitudes of zero as well. Vega and stars of the same spectral type actually put out less light in the V and U bands than in B, but because the system is calibrated in a relative way, this is not important.

Before we go any farther, let me mention that many other photometric systems have come into use. Invariably they are designed to try to determine specific properties of stars such as luminosity, temperature, metal content, and so on. They usually have more filters with narrower bandpasses, yielding a greater number of colors (magnitude differences) and more information about stars than the good ol' UBV system. Because they are often tailored for specific kinds of stars, they are rarely used on galaxies — which are essentially huge collections of all kinds of stars — and thus needn't concern us for the moment.

However, one of the reasons for starting this series are magnitudes of galaxies derived from photographic measurements. These are fraught with a variety of problems and, most importantly, are frequently misunderstood in amateur publications.

The colors of most stars vary as a function of temperature. When we talk about photome-

try, "colors" means a "color-index," defined as the difference between the magnitudes in two filters. For the purposes of our discussion, we need only deal with the two filters B and V because the dark-adapted visual color response lies roughly between the bandpasses of these two filters and spreads over most of their range.

Ordinary stars range in B-V color from about -0.2 to around +1.5. The stars in the belt of Orion, for instance, are early B-type stars, and have B-V between -0.2 and -0.1, i.e., their B magnitudes are two tenths of a magnitude brighter than their V magnitudes. This means that Zeta Orionis, at the east end of the Belt, has B-V = -0.21 according to the fourth edition of the Yale *Bright Star Catalogue*.

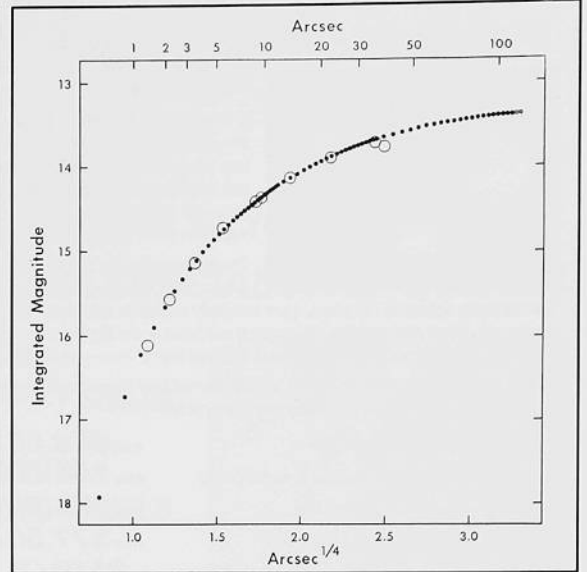
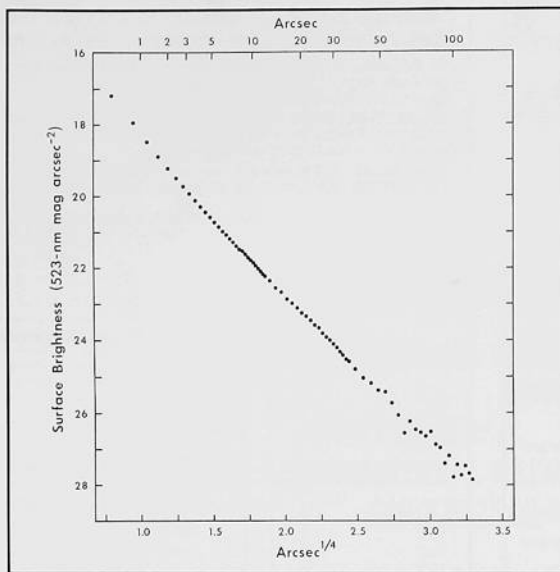
As already mentioned, Vega has B-V near 0.0. Yellowish K0III stars were said to have a color index of 1.0. Betelgeuse, the bright orange M-type supergiant in Orion, has a B-V = 1.85. Because it is a pulsational variable, its color changes by a few hundredths from this value as it brightens and fades. By now you get the idea: Hot, bluish stars have small, even negative B-V colors; cool stars have larger B-V values.

Up until now we've been dealing with stars. It is easy to use a photometer to measure their brightness since they are effectively point sources of light. But what happens if we want to know the magnitude of an extended object like a galaxy? And why do astronomers want to know magnitudes of galaxies, anyway?

It's certainly not because amateurs want to be able to see how faint they can go with their telescopes. Probably the most basic thing you could want to know about a celestial object is how much energy is coming from it, and this is essentially what magnitudes provide an estimate of. By knowing the

Figure 1 (right) shows the surface brightness of galaxy NGC 4881 as a function of surface brightness.

Figure 2 (far right) shows the integrated luminosity of NGC 4881 as a function of aperture radius. From Thompson and Baum, *ApJ*, 315:460 (1987 April 15).



apparent magnitude of a galaxy and an estimate of its distance, it is possible to derive the absolute magnitude and compare it with other objects. This way it's been found, for instance, that the brightest elliptical galaxies in rich clusters are as much as fifty times brighter than the Milky Way. At the other end of the scale, the least luminous galaxies known are no brighter (but still far larger) than an average globular cluster. These tidbits by themselves are not important *per se*, but are a start for further observational and theoretical inquiry. And we wouldn't know them without magnitudes for the galaxies.

Most galaxies have a relatively very bright center and fade gradually until the halo seems to merge with the night sky. The deepest measurements of individual bright galaxies have extended out to where the galaxy has faded to a brightness of magnitude 29 per square arcsecond. The galaxies involved show no signs of stopping; it's only that the calibration of the magnitudes fails beyond this. But the darkest skies have a brightness of about V magnitude 22 per square arcsecond, so how can things be detected fainter than that?

The sky emits a certain amount of light per unit area, and that much energy we're calling magnitude 22 per square arcsecond. We make a measurement of the faint part of a galaxy and subtract a measurement of the sky alone. Let's say, for example, whatever is

left over is only 1 percent of the original amount. That measure corresponds to magnitude 27 per square arcsecond. (Remember five magnitudes corresponds to a brightness difference of 100.)

In practice, most astronomers don't get a measure of the sky brightness accurate to any better than 1 percent. This means that the calibration of surface brightnesses fainter than 1 percent of the sky brightness are dominated by errors in the calibration and become progressively less reliable at fainter levels.

Figure 1 shows a plot of the surface brightness of the Coma cluster galaxy NGC 4881 versus distance from the center of the galaxy from a high-precision study. In this case, the galaxy's brightness has faded to that of the night sky already at only 10 arcseconds radius. Despite great care taken in analyzing the data, the measurements become "noisy" (uncertain) beyond about magnitude 26 per square arcsecond, but hold well enough to magnitude 28 per square arcsecond, only 0.4 percent of the brightness of a perfectly dark night sky.

Studies like this down to very low light levels show that only a small fraction of the total light of a galaxy is emitted in the outermost regions: Less than 10 percent of the total comes from outside the magnitude 26 per square arcsecond isophote, even though the area involved is much larger than the inner, brighter portions of the galaxy.

Up until recently magnitudes

for galaxies were measured by taking readings of the brightness with different sized diaphragms in a photometer normally used for stars. A small pinhole would be centered on the nucleus and a reading taken (or several, probably, to allow for centering errors). Then a somewhat larger hole is put in the light path and more measurements are compared against additional measures of standard stars of known (and generally agreed upon) brightness, such that the magnitudes can be placed on the UB system.

The magnitudes going from small to large diaphragms will of course get brighter until they level out once most of the galaxy's light included. As long as enough measures are made (or collected from various sources), the growth in brightness can be extrapolated mathematically out to infinite radius. The result is called the "integrated" or "total" magnitude.

These days CCDs are used to measure the brightness of galaxies. These are photoelectric detectors like the photomultiplier used in a photometer, but register light over an area instead of a single spot. Standard stars must be measured as before in addition to other calibrations specifically to deal with the two-dimensional detector. Despite the additional work necessary to reduce the data, CCDs allow magnitudes to be determined within specific isophote levels, and total magnitudes can be extrapolated much as before.

Figure 2 depicts a plot of the growth in magnitude of NGC 4881 as greater radii are considered. (Just to confuse you, the magnitudes here are on a special system, and not the standard UB system.) The dots are newer CCD measures whereas the circles are old measures taken with a photoelectric photometer in different diaphragms as described above. The data agree well, but those from the CCD are more reliable simply because there are more of them. We now know the total magnitude of this galaxy to high accuracy.

Total magnitudes are designated B_T (B-sub-T) or V_T (V-sub-T). Typical B-Vs for elliptical galaxies are about 1.1, since their light is dominated by late-type stars (zillions of K-giants). Galaxy colors become progressively bluer (smaller) along the spiral sequence, until the irregulars, which have a typical B-V = 0.4. The average spiral has a B-V = 0.7, so B_T is 0.7 magnitudes fainter than V_T .

These magnitudes have a very specific meaning, and as we'll cover in detail in the next issue, should not be confused or equated with otherwise commonly quoted "photographic magnitudes." People are misleading themselves with the latter into thinking they're seeing a lot fainter than they really are. We're talking apples and oranges here, gang, and there are important consequences for visual observing.

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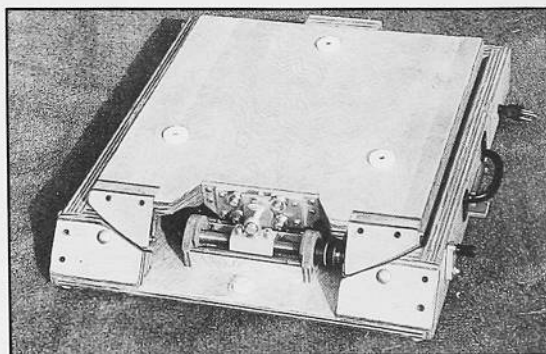
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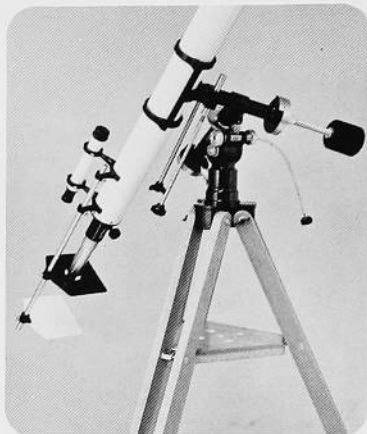
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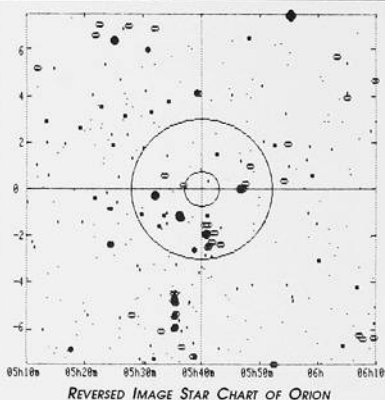
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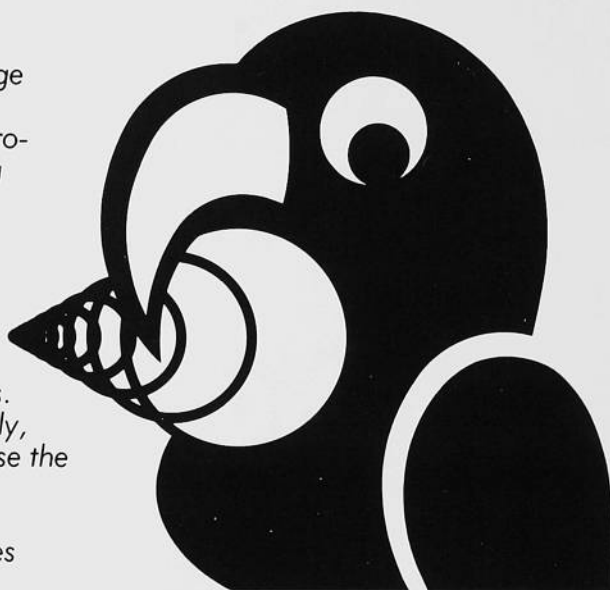
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